UNCLASSIFIED

AD NUMBER
AD024494
CLASSIFICATION CHANGES
TO: **unclassified**
FROM: **confidential**
LIMITATION CHANGES
TO: **Approved for public release; distribution is unlimited.**
FROM: **Controlling DoD Organization: Bureau of Naval Personnel, Washington, DC.**
AUTHORITY
Office of Naval Research ltr dtd 26 Oct 1977; Office of Naval Research ltr dtd 26 Oct 1977

THIS PAGE IS UNCLASSIFIED

CONFIDENTIAL - SECURITY INFORMATION

BUREAU OF NAVAL PERSONNEL TECHNICAL BULLETIN 53-2

Guided Missile Personnel Research: Report No. 2

Part Two; Volume 2

A COMPILATION OF TASK INFORMATION FOR TERRIER MISSILE ACTIVITIES

Prepared under the Sponsorship of the

BUREAU OF NAVAL PERSONNEL

ROBERT GLASER, Project Director

JACK HAHN

JOHN C. PHILLIPS

AMERICAN INSTITUTE for RESEARCH

PITTSBURGH, PENNSYLVANIA

CONFIDENTIAL — SECURITY INFORMATION

SECURITY INFORMATION

BUREAU OF NAVAL PERSONNEL

* RESEARCH REPORT *

Guided Missile Personnel Research: Report No. 2

Part Two, Volume 2

A COMPILATION OF TASK INFORMATION FOR TERRIER MISSILE ACTIVITIES

by

Robert Glaser, Project Director

Jack Hahn

John C. Phillips

American Institute for Research

Pittsburgh, Pennsylvania

August 1953

Prepared under Contract N7onr-37008, NR-152-079

TRAINING RESEARCH BRANCH AND

BILLET AND QUALIFICATIONS RESEARCH BRANCH

PERSONNEL ANALYSIS DIVISION

45

5444-4993B

SECURITY INFORMATION

CONTENTS

PART TWO—A COMPILATION OF TASK INFORMATION FOR TERRIER MISSILE ACTIVITIES

Volume 2	Page
SUPPLEMENT ONE: A TECHNICAL SUMMARY OF THE TERRIER MISSILE .	205
Terrier Missile Functioning: a brief overview	209
Terrier Technical Notes	215
Superheterodyne Receiver	216
Intelligence Converter	231
Missile Computer and Servo Amplifier	241
Roll Stabilization System	258
Electrical System	268
Programmer	278
Pneumatic-Hydraulic System	286
SUPPLEMENT TWO: A COMPARISON OF TERRIER SUBJECT MATTER WITH STANDARD CURRICULUM MATERIAL	295
Receiver Section	296
Intelligence Converter Chassis	297
Computer Chassis	297
Servo Amplifier Chassis	297
Roll System Units	298
Electrical System - Power Supply	298
Electrical System - Booster Firing Circuit	299
Electrical System - Power Changeover System	300
Programmer Chassis	300
Pneumatic-Hydraulic System	300

SUPPLEMENT ONE

A TECHNICAL SUMMARY OF THE TERRIER MISSILE

SUPPLEMENT ONE: A TECHNICAL SUMMARY OF THE TERRIER MISSILE

The technical summary given here consists of two parts:

1. Terrier Missile Functioning; a brief overview
2. Terrier Technical Notes

The first part describes the technical features of the Terrier system in terms that are understandable to individuals with a minimum of technical background. The second part, the Terrier Technical Notes, are a set of notes which present an engineering analysis of the Terrier missile. These notes presume some technical knowledge on the part of the reader.

It is intended that the first part of this technical summary, Terrier Missile Functioning, be read by individuals in personnel agencies who do not require the more detailed information in the Terrier Technical Notes. As a secondary function, it is intended that Terrier Missile Functioning serve as introductory material which should be read before reading the Technical Notes.

The Terrier Technical Notes were written by a group of engineering consultants who participated in the construction of the Terrier missile proficiency test battery.[1] The information contained in these notes was obtained from material available in the Terrier missile file compiled by the American Institute for Research. An index of these materials is presented in Section 2 of this report.

The notes were developed for the following reasons:

1. to facilitate an understanding of the operation of the Terrier missile.
2. to save time in locating technical and descriptive material.
3. to assure complete coverage of the Terrier missile by the proficiency test items.

The notes are included in the compilation of task information to serve similar ends for Navy personnel agencies.

---

[1] See Guided Missile Personnel Research: Report No. 3, A proficiency test battery for guided missile technicians, American Institute for Research, August 1953.

For the purpose of this analysis, the Terrier missile was divided into seven sections or sub-systems. Each section was then divided into a number of stages; a stage is defined as a functional unit, usually a group of components, which operates upon, or in some manner modifies, a signal in a prescribed manner.

Information for each of the seven sections and wherever pertinent for each of the stages has been classified into the following categories:

Function: A description of the operation, or modification which the section or stage performs upon the signal(s) fed into it.

Input: A brief description of the signal(s) that are fed into the section or stage as well as the immediate source of the signal(s). Static voltages such as bias and d-c plate supply voltages are not included.

Operation: The method by which the signal is operated upon or modified.

Output: A brief description of the signal(s) coming out of the section or stage, and the name of the missile section or stage to which the signal(s) is sent.

Tests: A listing, primarily, of the tests that are performed by special Terrier equipment. For the most part, shop and bench testing has not been covered. The word "none" in this category means that the stage is tested only indirectly or not at all with special Terrier test equipment.

Location: Information about the relative location of the section or stage in the missile.

References: A listing of the sources of information employed in the writing of a particular part of the notes.

For each of the stages, the following category of information is included in addition to the ones listed above:

Principles: A listing of the basic principles (electronic, mechanical, or hydraulic-pneumatic) used in the stage.

The following should be pointed out concerning the Technical Notes which follow:

1. The analysis was made while Terrier was still undergoing some development; therefore, some changes will probably occur in certain sections of the missile.

2. These notes were written by engineers primarily for their own use and the use of other engineers.

3. Special Terrier test equipment is not analyzed in these notes because manuals for most of the test equipments were already available which presented adequate sources of information for the purpose of test construction.

Terrier Missile Functioning; a brief overview

The Terrier missile is a rocket-propelled, beam-riding, surface-to-air missile.

Terrier is used in conjunction with a radar beam which automatically tracks the target. The beam, as it leaves the transmitting antenna, has been focused much as a searchlight beam can be focused. As in the case of the searchlight beam, the radar beam can be said to occupy a volume in space, that is, the beam has thickness. In the searchlight beam there is a line of maximum intensity of illumination which extends through the length of the beam. Intensity of illumination decreases with increasing radial distance from this line. Similarly, in the radar beam there exists an axial line through the beam which is the line of maximum power. The signal strength at any given point in the beam is a function of radial distance from the line of maximum power. As radial distance increases, signal strength decreases.

In addition to the motion of tracking, the beam is routed about the direct line to the target in such a manner that the line of maximum power continually traces out a cone with its vertex at the transmitting antenna, as the target is being tracked. The rate of rotation is 30 revolutions per second.

Figure 1 shows the cone generated by the line of maximum power as it rotated about the line connecting the antenna and the target. Note that the dotted line in Figure 1, connecting the antenna and the target, is also the center line of this cone.

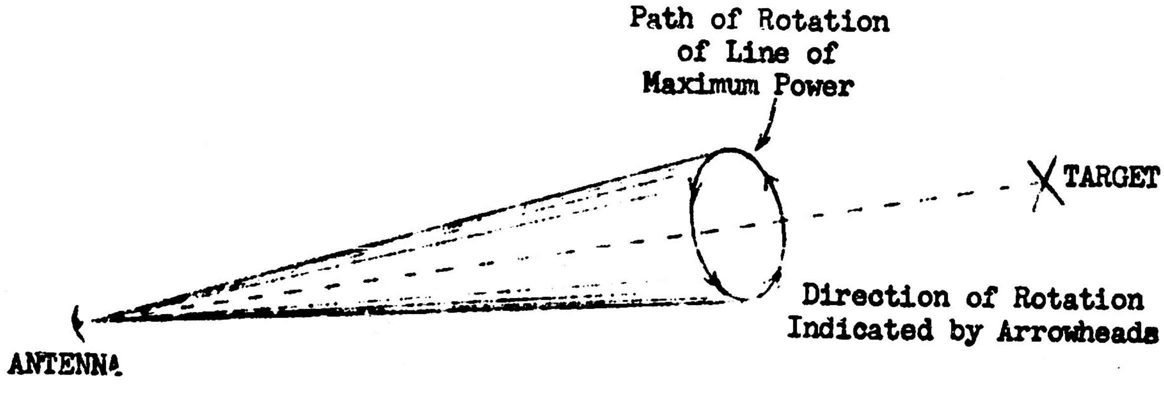


Figure 1

Cone Generated by the
Line of Maximum Power

The automatic tracking makes it possible to keep the cone centered about the target. The function of the various guidance circuits in the missile is to keep the missile as near as possible to the cone center.

As the missile flies toward the target, it picks up signals from the radar beam. When the missile is exactly in the center of the cone, the path traced by the line of maximum power is always equidistant from the missile; and the strength of the signal received by the missile, which is a function of missile distance from the line of maximum power, does not vary as the beam sweeps through its path of rotation.

If the missile strays from the cone center, however, it is at certain points in the beam cycle, closer to the path of the line of maximum power than it is at other points, as shown below in Figure 2.

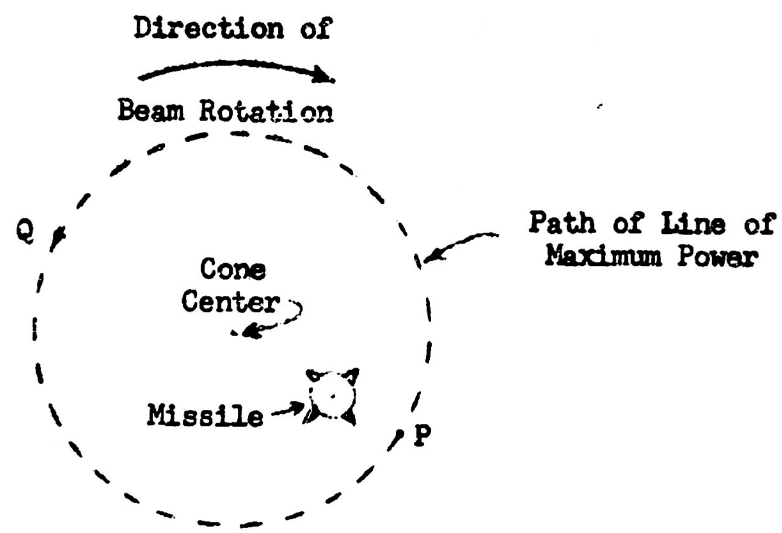


Figure 2

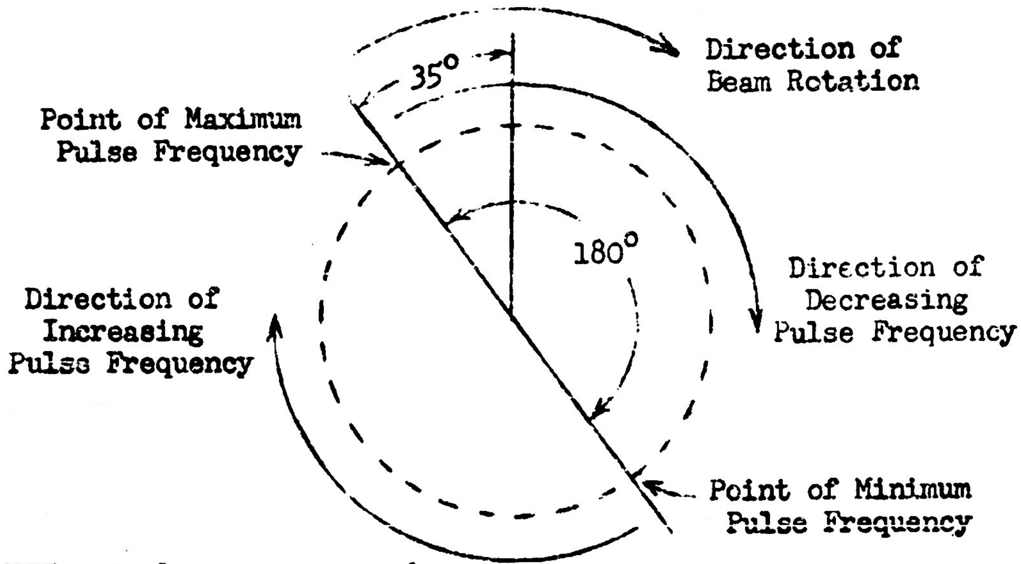
Cross-section of Cone with Observer Looking up the Cone (from antenna to target)

In the diagram shown, the radar signal received by the missile has a maximum strength at the instant the line of maximum power is at point P, and a minimum strength when the line of maximum power is at point Q. In other words, when the missile is in an off center position in the cone, the signal it receives varies in amplitude from a maximum to a minimum for each rotation of the beam. Thus, when the missile is off center, the signal has "amplitude modulation." As the missile's distance from the cone center

increases (but the missile is still within the cone) the maximum signal strength increases and the minimum signal strength decreases. In other words, the amount of amplitude modulation present is a function of the distance the missile has departed from its desired position in the center of the cone. Since the beam rotates 30 times a second, the amplitude modulation varies from a maximum to a minimum and then back to a maximum again at a 30 cps rate.

In order that the missile return to the center of the cone, it is necessary that it receive "information" not only regarding its distance from the center, but also regarding its direction from the center.

This is accomplished as follows. A radar beam normally transmits energy in pulses. That is, it normally is "ON" for a brief instant and then "OFF" for a much longer period of time. Normally, the time interval between pulses is constant. In the Terrier radar this time interval varies and is a function of beam angle with reference to an imaginary vertical plane in space. When the beam is at an angle of 35°, counter-clockwise from vertical (see Figure 3), the interval between pulses is at a minimum (frequency of pulses is highest). As the beam rotates clockwise, the time



NOTE: Angles are measured, as shown, within the plane of cross-section.

Figure 3

Cross-section of Cone with Observer Looking up the Cone (from antenna to target)

interval increases (frequency of pulses decreases) until, when it has rotated 180°, the interval between pulses is a maximum (frequency of pulses is lowest). As the rotation continues, the interval decreases (frequency increases once more) until a full 360° has been covered and the interval is again at its minimum value.

Since in this process the frequency of the pulse is varied, this is called "frequency modulation." Since the maximum and minimum pulse frequencies correspond to fixed angles with reference to the vertical, and since the frequency varies smoothly between these two points, the missile has available an angular reference system. As in the case of the a-m, the f-m completes one cycle for each revolution of the beam, and there are therefore 30 cycles of f-m every second.

When the a-m, and the f-m, present in the signal are combined, through suitable electronic circuitry, the missile has available position information regarding its distance and direction from cone center. This signal can then be used to deflect the missile wings in such a direction that the missile moves towards cone center. In the Terrier missile, two independent pairs of wings are used. One pair (the "A" wings) lie in a plane 45° to the left of the vertical plane and when deflected can cause the missile to fly either Up Right or Down Left. The other pair (the "B" wings) are located in a plane 45° to the right of the vertical and when deflected can cause the missile to fly Up Left or Down Right.

The electronic circuitry is such that the appropriate signals are always sent to the proper wings to cause the missile to return to the center of the cone.

The discussion just completed implies that the "A" wings always lie in a plane 45° to the left of vertical and that the "B" wings always lie in a plane 45° to the right of the vertical. If this does not occur, then the signals sent to the wings will not cause the missile to return to center of the cone. It therefore becomes necessary to utilize some means to insure that the missile maintains its proper orientation in space. This is done thru the use of a roll free gyro. The gyro maintains a fixed reference in space; and when the missile rolls from the desired orientation, a signal is sent to an amplifying system and eventually to two fin type control surfaces called rollerons, which deflect in a direction to cause the missile to roll back towards its desired orientation. It should be noted that roll stabilization is independent of the emitted radar signal, and in fact is a prerequisite to the missile's proper use of information extracted from the radar beam.

In order to obtain the guidance and roll stabilization information discussed above, the missile is provided with two major electronic packages:

1. The Receiver package
2. The Guidance package

A receiving antenna is mounted in one of the missile tails. This picks up the radar signal, which is then fed to the receiver. The receiver amplifies tha radar beam signal and extracts the amplitude and frequency modulation information contained in the beam. (In most technical discussions of Terrier operation, the amplitude modulation information is referred to as the "error" signal, and the frequency modulation information is referred to as the "reference" signal.) In addition, the receiver contains a decoding circuit whose function is to cause the missile to respond only to a radar beam with a specific coding. The receiver also contains a circuit which causes the missile to self-destruct under certain prescribed conditions.

The guidance package makes use of the reference and error signals coming from the receiver. The reference signal is split into two signals which have a specific time relationship to each other (90° phase relationship), which corresponds to the 90° space relationship of the two pairs of wings. Each of these signals is then combined with the error signal to obtain two voltages, one for the "A" wing and the other for the "B" wing, which are functions of the missile's distance and direction from cone center. Each of these signals is then fed to a computer which modifies the signal so that flight characteristics are improved. From the computers each signal is sent to a servo amplifier which translates the signal into a directly proportional movement of the wings. This movement is controlled by the electrical signal which controls the position of a hydraulic valve and allows oil pressure to move an actuator connected to the wings. The oil pressure is maintained by a hydraulic system discussed below.

The electronic circuitry involved in roll stabilization is also located in the guidance package. The roll free gyro, located outside of the guidance package, provides a voltage which is a function of roll error magnitude and direction. (Roll error refers to the missile's deviation from the desired roll position.) This voltage is amplified and modified in certain predetermined ways so that improved flight characteristics are obtained. The signal is then sent to a servo amplifier which controls rolleron movement. The operation is very similar to the equivalent system used in the "A" and "B" wing channels.

The electrical power required for the operation of the missile's electronic and electrical circuitry, and the hydraulic power to actuate the wings and rollerons come from a common primary power source. The power source for these purposes is the missile air flask. Compressed air is stored in this flask at a pressure of 4,000 psi. This air is reduced in pressure to 600 psi and used to operate a hydraulic pump (the autopak), which maintains a pressure of 1800 psi in the high pressure side of a closed-loop hydraulic system.

The hydraulic pressure is used for the following functions:

1. <u>To actuate the wings and rollerons</u>

   When a signal comes from one of the servo amplifiers, a corresponding hydraulic valve is opened. This permits hydraulic flow into a chamber, which causes an actuator connected to the control surface (wing or rolleron) to move in the desired direction.

2. <u>To drive a hydraulic motor</u>

   The hydraulic pressure is used to drive a hydraulic motor, which, in turn, drives an alternator that produces 115 volt, 3 phase, 400 cycle alternating current.

The voltage from the alternator is fed to the power supply package (the third major electronic package) where the voltage is transformed to the values required for missile circuitry. Some of these voltages are then rectified and filtered so that d-c voltage is available. Some of these d-c voltages are then fed directly to the missile circuits requiring them; others are "regulated" and then fed to the rest of the missile.

The power described thus far is used only to energize and activate the missile guidance system. The air flask and power derived from it is not used to propel the missile. All thrust utilized by the Terrier missile in flight originates from two solid propellant rocket motors. One, called the booster, provides the initial thrust to attain operating velocity. After the booster burns out, it falls away from the rest of the missile and in doing so pulls a lanyard which activates a second rocket the sustainer. The sustainer provides sufficient thrust so that the approximate velocity reached at the end of the booster phase is maintained for the duration of powered flight.

Terrier Technical Notes

TERRIER COMPONENT SYSTEMS

1. Superheterodyne Receiver
2. Intelligence Converter
3. Missile Computer and Servo Amplifier
4. Roll Stabilization System
5. Electrical System
6. Programmer
7. Pneumatic-Hydraulic System

SUPERHETERODYNE RECEIVER

1. Superheterodyne Receiver
- 1.1 R.F. System
  - 1.1.1 Antenna: Teflon Lens
  - 1.1.2 Waveguide Shutter
  - 1.1.3 Crystal Mixer
  - 1.1.4 Local Oscillator
- 1.2 I.F. System
- 1.3 Pulse Detector
- 1.4 Pulse Shaper and Video Amplifier
- 1.5 Pulse Decoder
- 1.6 Pulse Stretcher
- 1.7 Reference Channel Blocking Oscillator
- 1.8 Reference Channel F-M Discriminator
- 1.9 Negative Boxcar Detector
- 1.10 Automatic Gain Control
- 1.11 Automatic Frequency Control System
- 1.12 Flight Limiter Circuit

1. SUPERHETERODYNE RECEIVER*

Function: To convert coded and modulated ** microsecond radar pulses into 30 cps error and reference signals.

Input: The Mark 25 Mod 6 radar set emits microsecond mc pulses. When received by the missile, the pulses are frequency modulated at a 30 cps rate and have a deviation of pps around a mean of pps. If the missile is off cone center 30 cps amplitude modulation is also present.

Operation: The superhet receiver heterodynes the input signal from the radar set and that from the local oscillator. The difference frequency is then amplified and detected. The resulting pulses are decoded. After being amplified and stretched, the pulses are processed to obtain the reference and error information. This information appears in the output as two 30 cps sinusoidal waves; one being the reference signal, and the other being the error signal.

Output: (1) 30 cps reference signal to reference phase splitter in intelligence converter.
(2) 30 cps error signal to $f_1(t)$ pot in intelligence converter.
(3) Pulse to destructor in event of weak or off-frequency signal.

Test: The receiver may be tested as a unit or as part of the Terrier system. In both cases, the Beam Simulator provides the necessary input signal into the missile waveguide. The Flight Ready Indicator will give out-of-tolerance readings if certain receiver defects exist. The set-up Monitoring Panel will check the Receiver directly.

---

* Lot IV Terrier has two types of receivers--a Ground Based Local Oscillator System (GBLO) and a Superhet System (SH). The GBLO receiver has no local oscillator but receives two simultaneous pulses having a difference in frequency of mc. The SH receiver has a self-contained local oscillator using a klystron with automatic frequency control. The radar is also changed accordingly.

** At certain points in this text it has been necessary to delete numerical values or other material whose classification is higher than CONFIDENTIAL.

References:

Beam Characteristics	OP 1956	pp. 1-7
	OP 1955	pp. 9-17
Receiver Action	OP 1956	pp. 7-11
Receiver Location	OP 1955	p. 16
Receiver Input Circuits	OP 1956	pp. 11-14
Receiver Tests		
	OD 8497	pp. 1-73
	OP 1956	pp. 140-44
	OP 1956	pp. 148-53
	OP 1956	pp. 121-31
	OP 1956	pp. 144-48
Output	OP 1956	pp. 17-18
Block Diagram	Term III Notes* Receiver Sec. 5.	
Circuit Diagram	OP 1956	p. 19
Parts List	OP 1956	p. 20
Superhet System	Term IV Notes Receiver Sec. 1.2, 1.4	
GBLO System	Term IV Notes Receiver Sec. 1.3	
	Term III Notes Receiver Sec. 1	
Location	OP 1955	p. 16

1.1 R.F. SYSTEM

Function: To receive modulated electromagnetic waves from Mark 25 Mod 5 radar at a frequency of about mc and to convert without loss of intelligence the above frequency to mc for the i-f strip.

Input: The mc frequency is transmitted in microsecond pulses. Pulse repetition frequency is varied from to pps at a rate of 30 times per second (f-m). Average PRF is pps.

---

* Throughout this analysis Term III Notes, and Term IV Notes, refer to notes produced by Convair Industrial Relations Dept., Customer Training Section.

The signal is transmitted by the Mark 25 Mod 6 Radar. The center of the lobe is at a small angle with the normal to the antenna. The lobe rotates clockwise around the normal 30 times per second forming a cone. The missile flies in the center of this cone. When the missile is off center, amplitude modulation is also present.

Two beams are provided--one is a wide angle, low power beam for capture; and the other is a narrow, high power beam for guidance.

Operation: The R.F. System receives electromagnetic waves from free-space and transmits them as guided waves to a crystal mixer. The waves are heterodyned in the crystal mixer with the local oscillator signal to provide a difference frequency of mc for the i-f strip.

Output: mc pulses into the i-f strip of receiver. The amplitude of this signal is proportional to the distance from the transmitter and instantaneous distance off center of the cone.

References:

Beam Characteristics	OP 1956	pp. 1-7

1.1.1 ANTENNA: TEFLON LENS

Function: (1) To match waveguide to free space.
(2) To pick up radar signals and reradiate them into waveguide.

Input: mc radar pulses from free space.

Characteristics: Length--4 3/8"; shape--circular and tapered toward each end. Half-power beam width is 40°. Exhibits a uniform pattern for both planes of waveguide.

Output: Feeds into a 3" teflon transition piece (waveguide-to-antenna matching section). The output depends on signal strength at antenna; some loss present in antenna.

Principles: Antenna characteristics, impedance matching.

Tests: None

Location: Located in fin #4. Held in place by Lens Retaining Nut.

References:

Electrical Characteristics	Term IV Notes Receiver Sec. 2.1	
Physical Characteristics	OP 1956	p. 11
Location	OP 1955	p. 39
Waveguide	Term IV Notes Receiver Sec. 2.2	
Waveguide	Term III Notes Receiver Sec. 2	
Waveguide	OP 1956	p. 12

1.1.2 WAVEGUIDE SHUTTER

Function: (Flange on booster is now being used on newer models instead of waveguide shutter.) To protect the crystal in the mixer from high level signal while missile is near launcher (during boost phase).

Operation: Guillotine type, spring loaded to hold it in closed position. It is withdrawn by a Ledex rotary type solenoid .1 second after booster separation. Solenoid controlled by programmer.

Principles: Waveguide transmission, mechanics of spring loaded shutters.

Test: Checked indirectly with Flight Ready Indicator and also Monitoring Panel.

Location: On waveguide between receiver package and tail fin, Aft Guidance Section, Quadrant 4.

References:	Term III Notes Receiver Sec. 2	
Description	OP 1956	p. 12

1.1.3 CRYSTAL MIXER (Superhet Receiver)

Function: To convert the mc signals into mc pulses (i-f frequency).

Input: (1) Pulsed waves from the radar, and
(2) CW waves from the klystron local oscillator.

Operation: The waveguide is terminated by a crystal (IN 23B). This crystal, being a non-linear impedance, conducts better in one direction than in the other, and therefore produces some degree of rectification for the incident signals.

[NOTE: In GBLO sets, the crystal is biased to 21 micro-amp point on characteristic curve (point of greatest efficiency). The crystal is kept at this operation point by a superimposed 30 cycle component from the error channel, which is always in phase with the a-m component of the received signal.]

Output: Several frequencies including fundamentals and sums and differences of fundamentals. Only the difference of mc is used.

Principles: Heterodyning, waveguide termination.

Test: Crystal tester.

Location: In waveguide after directional coupler.

References:

Operation	OP 1956	p. 12
Operation	Term IV Notes Receiver Sec. 2.3	

1.1.4 LOCAL OSCILLATOR

Function: To provide a low power C.W. R.F. signal to the heterodyne detector.

Input: A varying d-c signal to the reflector from the AFC system and a 0.22 v, 400 cps signal.

Operation: The reflex type klystron local oscillator operates at a difference of mc with respect to the frequency of the

received radar signal. This difference is held constant by the AFC circuit. The frequency of operation of the klystron is in the mc band.

Output: A slightly modulated low power microwave signal into a waveguide directional coupler. The directional coupler radiates a part of this signal into the main waveguide and in the direction of the crystal detector.

Test: Measure for presen of crystal current with no signal into the external waveguide coupling.

Principles: Reflex klystron, directional couplers.

References:

Diagram	Convair Drawing No. 4388-430017	
Operation	Term III and IV Notes Receiver Sec. 11	
Test	OD 8497	p. 17

1.2 I-F AMPLIFIER

Function: To amplify the microsecond pulses.

Input: microsecond mc pulses from crystal mixer.

Operation: 90 db gain over a band width of 6.5 mc. The tubes used are 5899 remote cut-off pentodes. AGC bias is used together with cathode bias. The strip is made up of two groups of three stages (two sets of staggered triples). In first group the stages are tuned to , , and mc. In second group they are tuned to , , and mc. The first two stages of each group have a quality factor of 15. The mc stage has a quality factor half as large.

Output: A greatly amplified (90db max.) version of input. Output is coupled to an IN23B crystal rectifier.

Principles: Tuned circuits, amplifiers, stagger tuning, remote cut-off tubes, AGC.

Test: Bench Test with Standard Signal Generator No. 60, Hewlett Packard VTVM 410A, and Lambda Power Supply.

Location: I-f, Video, Flight Limiter Chassis in Radar Receiver, Aft Guidance Section, Quadrant 1.

References:

General Description	OP 1956	p. 12
General Description	Term III Notes Receiver Sec. 3	
Operation Detailed	Term IV Notes Receiver Sec. 3.0	
Alignment	Term IV Notes Receiver Sec. 3.0	

1.3 PULSE DETECTOR

Function: To convert the mc pulses into negative d-c pulses.

Input: microsecond mc pulses from last i-f stage.

Operation: The IN 23B crystal is used as a rectifier. An RC filter is used in the cathode circuit.

Output: Negative microsecond d-c pulses into a pulse shaping circuit and video amplifier.

Principles: Detection, RC filters.

Test: No direct test; correct operation of receiver indicates correct detector operation.

Location: I-f, Video, Flight Limiter Chassis in Radar Receiver, Aft Guidance Section, Quadrant 1.

References:

Operation and Circuit Analysis	OP 1956	p. 13
General Description	Term III Notes Receiver Sec. 4	
Circuit Analysis	Term IV Notes Receiver Sec. 4.0	

1.4 PULSE SHAPER AND VIDEO AMPLIFIER

Function: (1) To amplify the d-c pulses, and
(2) To change these pulses from a negative to a positive polarity.
(3) To shape the video pulse in some models.

Input: Negative microsecond unidirectional pulses from detector. (From delay line in some models.)

Operation: RC coupled amplifier and cathode follower.

Output: Positive microsecond unidirectional positive pulses. Output fed into decoder.

Principles: RC coupled amplifiers, cathode followers.

Test: None

Location: I-f, Video, Flight Limiter Chassis, Radar Receiver, Aft Guidance Section, Quadrant 1.

References:

Operation	OP 1956	p. 13
Operation	Term III Notes Receiver Sec. 4	
Operation	Term IV Notes Receiver Sec. 4	

1.5 PULSE DECODER

NOTE: Due to security reasons, the decoder will not be discussed here.

1.6 PULSE STRETCHER

Function: To stretch the microsecond pulses to 15 microsecond pulses.

Input: Positive microsecond pulses at an average rate of per second (microsecond average spacing).

Operation: The input pulse charges a condenser through the relatively low forward resistance of a diode (triode with grid and plate connected). The condenser discharges through a higher resistance giving a longer pulse duration. The amplitudes of input and output pulses are proportional.

Output: 15 microsecond pulses with amplitudes proportional to the input pulses.

Principles: Diode rectifiers, RC circuits.

Tests: None

Location: Demodulator Chassis, Radar Receiver, Aft Guidance Section, Quadrant 1.

References: Convair Drawing No. 4388-430029

1.7 REFERENCE CHANNEL BLOCKING OSCILLATOR

Function: To remove the a-m from the pulses, leaving the frequency modulation.

Input: Amplitude modulated 15 microsecond pulses at an average rate of pps with ± 5% frequency modulation at 30 cps.

Operation: The 15 microsecond pulses are used to trigger a blocking oscillator.

Output: Appriximately two cycles of rapidly damped oscillations about 2 microseconds in duration. All output pulses are of constant amplitude. One output is fed to the error detector and used as a trigger pulse. Another output goes to the discriminator pulse stretcher where it is stretched to 30 microseconds and then fed into the discriminator.

Principles: Blocking oscillators, vacuum tube amplifiers, and regeneration.

Tests: None

Location: Demodulator Chassis, Radar Receiver, Aft Guidance Section, Quadrant 1.

References:

Description	OP 1956	pp. 14-15
Analysis	Term III Notes Receiver Sec. 6	
	Term IV Notes Receiver Sec. 6	

1.8 REFERENCE CHANNEL F-M DISCRIMINATOR

Function: To demodulate the constant amplitude, frequency modulated 30 microsecond pulses.

Input: A train of 30 microsecond pulses frequency modulated with 30 cps. Frequency is varied from to pps with an average of pps (± 5%).

Operation: Series and parallel tuned circuits are used to produce an output voltage of about +45 v at pps, a greater value above this frequency and a smaller value below this frequency. The change in voltage is proportional to the change in pps from the middle frequency. Since the change in pps occurs at the rate of 30 cps, the output changes at the same rate from approximately +30 v to +60 v with +45 v as a mean.

Output: A 30 cps wave having a 15 v amplitude superimposed on a +45 v d-c voltage. This output is filtered by a 30 cps filter and coupled to the intelligence converter by a cathode follower.

Principles: Tuned circuits, frequency discriminators, cathode followers, superposition.

Test: The f-m discriminator is tested as a part of the receiver.

Location: Demodulator Chassis, Radar Receiver, Aft Guidance Section, Quadrant 1.

References:

Description	OP 1956	p. 14
Operation	Term IV Notes Receiver Sec. 7.0	
	Term III Notes Receiver Sec. 7	

1.9 NEGATIVE BOXCAR DETECTOR

Function: To detect the 30 cps a-m envelope. The amplitude of this envelope is proportional to the deviation of the missile from the cone center.

Input: Amplitude modulated 15 microsecond pulses at an average frequency of pps. Also a reference pulse from blocking oscillator.

Operation: (See Convair blueprint 4388-430029.) 15 microsecond negative pulses coming from V-12 appear at the cathode of V-29. V-29 is normally non-conducting, but conducts during this 15 microsecond period. When V-29 conducts, C-408 charges to the value of the pulse from V-12. When V-29 stops conducting, C-408 remains essentially at the value it was charged to. Since the grid of V-14 is tied to C-408, a negative voltage proportional to the original pulse from V-12 appears at its cathode.

This condition exists until the next 15 microsecond pulse from V-12 appears. This triggers the blocking oscillator, V-20, (through V-19) which causes a positive pulse of very brief duration to appear at the grid of V-13. V-13 conducts, and this causes C-408 to discharge. The 15 microsecond pulse has a much longer duration than the pulse from the blocking oscillator and persists after C-408 has been discharged. This enables C-408 to charge once more, through the conduction of V-29, to the amplitude of the new pulse from V-12.

Output: A 30 cps wave proportional to the deviation of the missile from the cone center. The output is filtered, amplified, and coupled to the intelligence converter by a cathode follower. An output is also available for telemetering.

Principles: Detection, pulsing, and RC circuits.

Test: Error channel is tested as a part of the Receiver System.

Location: Demodulator Chassis, Radar Receiver, Aft Guidance Section, Quadrant 1.

References:

Description	OP 1956	pp. 14-15
Analysis	Term III and IV Notes Receiver Sec. 8	

1.10 AUTOMATIC GAIN CONTROL

Function: To maintain the output of the receiver at a fairly constant level over its operating range.

Input: A negative signal proportional to the average error signal and 1/6 of the 30 cps error signal, both from the boxcar detector.

Operation: (See Convair blueprint 4388-430029) The negative signal causes the grid of V-17 to be driven more negative, thereby allowing the cathode to go more negative. The cathode of V-17 is connected to the i-f grids through a low time constant RC network.

Output: (1) A low voltage d-c signal with an amplitude (negative) proportional to the average error signal, and
(2) a small component of the 30 cps error signal with an amplitude (negative) proportional to the deviation of the missile from cone center.

Tests: Tested only as part of the Receiver System.

Principles: Amplifiers, filters, voltage dividers, remote cut-off tubes.

Location: Demodulator Chassis, Radar Receiver, Aft Guidance Section, Quadrant 1.

References:

Description	OP 1956	p. 17
Operation	Term III Notes Receiver Sec. 9	
	Term IV Notes Receiver Sec. 9	

1.11 AUTOMATIC FREQUENCY CONTROL SYSTEM

Function: To maintain the local oscillator signal frequency at a value   mc from the incoming radar signal.

Input: Two 400 cps signals, one from the error detector and one from the 400 cps source. (The signal from the error detector is 400 cps only under certain conditions. See below.)

Operation: The klystron local oscillator is frequency modulated with a 0.22 v, 400 cps signal. This 400 cps signal is also fed into a phase comparator. Because of the slope of the i-f response curve, the 400 cps f-m is converted into 800 cps a-m when the i-f frequency is mc and 400 cps when the i-f frequency deviates from this value. This a-m is detected, amplified, and fed into the phase discriminator. The phase discriminator produces a d-c signal from the two signals which adds to or subtracts from the -200 v supply voltage on the reflector. This change in reflector voltage changes the local oscillator frequency in a direction that makes the i-f frequency closer to mc.

Output: When the i-f frequency is high, the phase comparator produces a positive voltage that reduces the negative repeller voltage. The output of the comparator is zero when the i-f frequency is mc and the modulation frequency is 800 cps. When the i-f frequency is low, the comparator produces a voltage that makes the klystron repeller more negative.

Principles: Phase comparators, filters, amplifiers, cathode followers.

Location: Not known.

References:

Operation	Term III Notes Receiver Sec. 11	
	Term IV Notes Receiver Sec. 11	
Diagram	Convair Drawing 4388-430017	
Test	OD 8497	p. 20

1.12 FLIGHT LIMITER

Function: To destroy the missile in the event that the signal level drops below a certain level, or the PRF changes more then pps from the normal pps.

Input: 30 microsecond positive pulses from the discriminator pulse stretcher at an average rate of pps.

Operation: (See Convair blueprint 4388-430029 A tuned circuit is used to relatively accentuate frequencies around cps. These signals are then coupled to a biasing network for V25 through a cathode follower and a diode. V25 is biased with a fixed voltage at or near current cut-off and the relay in its plate circuit is open. An incoming signal bucks out part of this negative bias and allows the tube current to increase and the relay close. C200 charges to 200 v with the relay closed. If the signal falls below a given level, the relay opens and C-200 discharges through the firing circuit, destroying the missile.

Output: 200 v pulse to firing circuit obtained from condenser discharge.

Principles: Vacuum tube operation, tuned circuits, RC circuits, and voltage dividers.

Test: Destruct circuit is checked with Beam Simulator and Monitoring Panel. This circuit may also be checked with the Beam Simulator and the Receiver Test Panel.

Location: All parts except relay located in I-f, Video, Flight Limiter Chassis, Radar Receiver, Aft Guidance Section, Quadrant 1.

References:

Description	OP 1956	p. 15
Operation	Term III Notes Receiver Sec. 10	
	Term IV Notes Receiver Sec. 10	
Diagram	Convair Drawing 4388-430029	
Test	OD 8497	p. 22
	OD 8495	p. 38

INTELLIGENCE CONVERTER

2. Intelligence Converter
   - 2.1 $F_1(t)$ Potentiometer and Error Amplifier
   - 2.2 Error Signal Driver
   - 2.3 Reference Phase Splitter and Driver
   - 2.4 Phase Comparator

2. INTELLIGENCE CONVERTER

<u>Function</u>: (1) To combine error and reference signals in such a way that two d-c error voltages may be obtained--one for "A" and one for "B" channel correction purposes.

(2) To compensate for changes in signal level with distance from transmitter.

<u>Input</u>: (1) A 30 cps error signal with an amplitude proportional to the distance from the cone center and a phase angle (with respect to the reference signal) proportional to the angular difference from a reference plane.

(2) A 30 cps reference signal of constant amplitude derived from the f-m signal and used for position reference.

<u>Operation</u>: The Intelligence Converter amplifies the 30 cycle error and reference signals out of the receiver and splits the reference signal into two sine waves having a phase difference of 90°. Each reference signal is then combined with the error signal in a separate phase detector to provide "A" channel and "B" channel d-c voltages proportional to error amplitude and phase.

The error gain is increased to compensate for decreased error magnitude due to increased distance between transmitter and receiver.

<u>Output</u>: Two d-c error voltages are fed to the missile computer--one for each channel. Both voltages are zero if the missile is on cone center.

<u>Tests</u>: The Flight Ready Indicator provides an indirect test. Proper intelligence converter functioning may be inferred if A and B meters give in-tolerance readings in switch positions D through G.

A direct test is provided by the phasing adjustments made when the MP is used for a missile systems test. Faults in the intelligence converter will result in incorrect behavior when the adjustments are made. Also, following the adjustment, the intelligence converter output is checked for several different programmer positions and radar beam strengths.

Detailed checks of the circuit functioning may be made with an oscilloscope and signal generator.

Location: Intelligence Converter Chassis, Guidance Package, Forward Guidance Section, Quadrant III and IV.

References:

Operation & Description	OP 1955		p. 15
	OP 1955		p. 41
	OP 1955		p. 47
	OP 1955		p. 50
	OP 1955		p. 62
	OP 1956	Fig. 2-4 to 2-9	pp. 21-29
		Fig. 5-19	p. 189
	Term IV Notes		
	Guidance Package		
	General Sec. 1.2.1		
	2		
	3		
	Special Sec. 2		
	3		
	4		
	5		
Tests	OP 1956	Fig. 5-11	p. 172
		Fig. 5-4	p. 167
	OD 8495		pp. 35-37

2.1 $f_1(t)$ POTENTIOMETER AND ERROR AMPLIFIER

Function: (1) To modify the 30 cps output of the receiver to account for radar beam divergence.
(2) To provide a high gain during the capture phase.
(3) To amplify the error signal to the level necessary for driving the error signal driver.

Input: Error signal from the receiver. This is a 30 cps signal having amplitude data (distance from cone center) and phase data (direction off) with respect to the reference signal.

Operation: The error signal is applied to a resistor and potentiometer in series. (For details of potentiometer operation see programmer position potentiometer.) The potentiometer pickoff is driven by the programmer motor so as to pick off a larger fraction of the receiver output signal as the missile travels up the beam. The series resistor is shorted by one contact of the capture relay until it is activated at the end of the capture phase. During the guidance phase this relay opens, removing the short, and simultaneously inserting a shunting resistor to ground so that the gain is sharply reduced.

The error amplifier provides a stage of normal amplification to bring the signal level back up to the values needed to operate the error signal driver properly.

Output: Modified error signal to the error signal driver.

Principles: Pentode amplifiers, potentiometers.

Tests: Indirect with Flight Ready Indicator, see Intelligence Converter. Direct with Monitoring Panel as part of test of Intelligence Converter made after phasing adjustment. The Computer input is measured for several positions of the programmer to provide a rough check of the $f_1(t)$ potentiometer and capture relay operation.

Location: The $f_1(t)$ potentiometer and capture relay are on the programmer chassis. The error amplifier is on the intelligence converter chassis. Both are in Guidance Package, Forward Guidance Section, Quadrant III and IV.

References:

Operation & Description	OP 1956	Fig. 2-4	p. 22
	OP 1956	Fig. 2-7	p. 25
	OP 1956		p. 26
	OP 1956	Fig. 2-8	p. 27
	OP 1956	Fig. 2-9	p. 28
	OP 1956		p. 36
	Term IV Notes Guidance Package		
	General Sec. 2.4		
	Special Sec. 3.1		
Test	OD 8495		pp. 35-37

2.2 ERROR SIGNAL DRIVER

Function: To amplify the error signal and convert it to a push-pull signal.

Input: Error signal from error amplifier.

Operation: The two triodes are cathode coupled. The grid of one tube is driven by the error signal from the error amplifier. The other tube is driven by the drop across the common cathode resistor. The phase of the two grid signals differs by 180° and the output is push-pull across the input of a transformer.

Output: An error voltage to the "A" and "B" channel phase detector networks.

Principles: Paraphase cathode coupled (push-pull) amplifiers.

Test: Indirect with Flight Ready Indicator and Monitoring Panel, see Intelligence Converter. Direct with signal generator and oscilloscope.

Location: On Intelligence Converter Chassis, Guidance Package, Forward Guidance Section, Quadrant III and IV.

References

Operation & Description	OP 1956	Fig. 2-4	p. 22
		Fig. 2-7	p. 25
		Fig. 2-8	p. 27
		Fig. 2-9	p. 28
	Term IV Notes		
	Guidance Package		
	General Sec. 2.5		
	Special Sec. 3.2		
Tests	OD 8495		pp. 35-37

2.3 REFERENCE PHASE SPLITTER AND DRIVERS

Function: To provide two reference signals with 90° phase difference and a correct overall phase angle with respect to the reference signal.

Input: Reference 30 cps constant amplitude signal from the reference frequency discriminator and cathode follower.

Operation: A cathode coupled paraphase amplifier is used to amplify the reference signal. This amplifier works into two RC networks. Each network is capable of shifting its output voltage from 0° to about 90° with respect to the input voltage, or 180° with respect to ground (center tap between the two equivalent generators) by changing the value of the series resistor. The networks are adjusted to give a phase difference between the two outputs of 90° each with the proper phase with respect to the reference input. The "A" and "B" reference signals are each amplified to the level necessary for proper operation of the phase comparators by reference signal drivers which are similar in operation to the error signal driver. (See Sec. 2.2.)

Output: (1) A phase shifted reference signal to the "A" channel phase comparator.
(2) Another phase shifted reference signal (differing by 90° from the "A" channel) to the "B" channel phase comparator.

Principles: Cathode coupled push-pull paraphase amplifiers, RC networks, equivalent circuits, and vectors.

Test: Indirect test with Flight Ready Indicator, see Intelligence Converter. Direct test with Monitoring Panel where phasing adjustments are made. Further direct test possible with signal generator and oscilloscope.

Location: Intelligence Converter Chassis, Guidance Package, Forward Guidance Section, Quadrant III and IV.

References:

Operation & Description	OP 1956		p. 21
			p. 22
			p. 25
			p. 27
			p. 28
	Term IV Notes		
	Guidance Package		
	General Sec. 2.1		
	2.2		
	Special Sec. 4		
Tests	OP 1956	Paragraph 5-11	p. 172
		5-13	p. 173
	OD 8495		pp. 35-37

2.4 PHASE COMPARATOR

("A" Channel Discussed, "B" Channel is Identical)

Function: To produce a d-c output voltage proportional to both the amplitude of the error signal and its phase with respect to the reference signal.

Input: (1) A reference signal from a push-pull paraphase amplifier which is driven from the output of one of the phase shift networks.

(2) An error signal from the error signal driver. Each input signal appears across the secondary of a transformer. Each secondary is center-tapped.

Operation: The following conventions are used below:

"Output" refers to voltage measured from the centertap of the secondary of the reference transformer to the centertap of the secondary of the error transformer. Polarity of output always refers to polarity of the reference transformer centertap with respect to the error transformer centertap.

Upper case "E" represents over-all secondary voltage. Lower case "e" represents one-half of the secondary voltage.

Subscript "er" indicates error voltage.
Subscript "ref" indicates reference voltage.

Both error and reference transformer secondaries are coupled through a ring detector system.

The output voltage can be shown to be as follows:

a) If equal, in phase, voltages are applied the instantaneous output voltage is 1/3 of the instantaneous value of E_{er} and the polarity is positive. The d-c component is, therefore, 1/3 of .636 $E_{er_{max}}$ or .212 $E_{er_{max}}$.

If the ratio E_{ref}/E_{er} is 2/1 or greater the instantaneous output will be equal to the instantaneous value of e_{er}. The d-c component is then .636 $e_{er_{max}}$. The polarity is positive.

b) If E_{ref} and E_{er} are 180° out of phase the discussion above still holds but the output polarity is negative.

c) If E_{ref} and E_{er} have a 90° phase difference the output is a double frequency sine wave with a d-c component of zero.

d) If either signal is zero the output is zero.

e) The d-c component increases with both an increase in error signal amplitude and a decrease in phase angle from 90° to 0°.

Output: (1) "A" channel - a d-c voltage which is zero if the missile deviation is colinear with the "A" wings and increases in magnitude as the deviation direction becomes greater along the direction perpendicular to the "A" wings (error signal phase). This d-c voltage also increases as the deviation from the center of the cone increases (error signal magnitude). The polarity of this d-c signal (see conventions above) is negative if the error is down-left causing the missile to move up-right. The polarity is positive if the error is up-right causing the "A" wings to deflect the missile down-left.

(2) "B" channel - a d-c voltage which is zero if the missile deviation is colinear with the "B" wings and increases in magnitude as the deviation direction becomes greater along the direction perpendicular to the "B" wings (error signal phase). This d-c voltage also increases as the deviation from the center of the cone increases (error signal magnitude). The polarity of this d-c signal (see conventions above) is negative if the error is down-right causing the missile to move up-left. The polarity is positive if the error up-left is causing the "B" wings to deflect the missile down-right.

Principles: Network theory, superposition, Kirchoff's laws and rectification.

Test: Indirect with Flight Ready Indicator and Monitoring Panel, see Intelligence Converter. Direct with oscilloscope and signal generator.

Location: Intelligence Converter Chassis, Guidance Package, Forward Guidance Section, Quadrant III and IV.

References

Operation & Description	OP 1956	Fig. 2-4	p. 22
	OP 1956	Fig. 2-7	p. 25
	OP 1956		p. 26
	OP 1956	Figs. 2-8 to 2-10	pp. 27-30

	Term IV Notes	
	Guidance Package	
	General Sec. 2.6	
	3	
	Special Sec. 2.2	
	5	
Tests	OP 1956	p. 172
		p. 173
	OD 8495	pp. 35-37

MISSILE COMPUTER AND SERVO AMPLIFIER

3. Missile Computer and Servo Amplifier
   3.1 Isolating Amplifier
   3.2 Corrective Network and Filter
   3.3 Compensated D-C Amplifier
   3.4 First Limiter
   3.5 Gain Change Network
   3.6 Integrating Amplifier
   3.7 Fixed Limiter
   3.8 Integral Limiter
   3.9 Cathode Follower Output
   3.10 Inverse Pressure Potentiometer
   3.11 Servo Amplifier

3. MISSILE COMPUTER AND SERVO AMPLIFIER

("A" Channel, "B" Channel Identical)

Function: The missile computer modifies the output of the intelligence converter to supply the servo amplifier with a signal which insures optimum beam riding characteristics. The modifications consist of sensitivity, gravity trim and altitude corrections and limiting effects.

Input: "A" channel d-c signals from the intelligence converter, and various gain change signals from the Programmer. The latter will be discussed under the appropriate subsection of Missile Computer.

Operation: The d-c signal leaving the Intelligence Converter is applied first to two circuits simultaneously. One is a compensated isolating amplifier of unity gain which provides a signal for telemetering purposes. The other is an RC correcting network and filter, which provides signal lead (to correct for normal guidance system lag). To compensate for the attenuation produced by the correcting network a compensated d-c amplifier of gain 27 follows the RC network. The output of the amplifier is fed thru a gain fixing network to a gain change network which is operated by the programmer to vary the gain of the channel. The maximum d-c swing at the input to the gain change network is fixed at 18.8 volts on either side of the zero signal level of -100 volts by the first limiter. The output of the gain change network is fed to an integrating amplifier which performs the averaging process necessary to determine the average wing signal required from the widely varying radar signal. The output of this amplifier is a function of both the strength of the error signal and its duration. That is, the longer the missile flies an error path with respect to the cone center the greater the missile wing incidence will become to correct for this error. The effect of this is to increase missile maneuverability and reduce any tendency for the missile to oscillate about the cone center. The output of the integrating amplifier is limited in amplitude by the fixed limiter and regeneration (which produces the error signal duration function) is limited by the integral limiter.

The signal goes from the limiting circuits to a cathode follower which provides impedance transformation to drive a low impedance potentiometer input. The output of the potentiometer is fixed by a sylphon bellows to provide altitude compensation for air density. From this potentiometer the signals pass to the $f_2(t)$ potentiometer of the programmer which provides compensation for changes in Mach number, center of gravity and weight during the flight. Following the $f_2(t)$ attenuator the signal goes to the servo amplifier which provides the power necessary to operate the hydraulic valves controlling the control surface deflections.

Output: D-C signal to the "A" servo-amplifier.

Tests: The Flight Ready Indicator provides an indirect test of computer operation in switch positions D through G. Tolerance readings in these positions implies proper functioning of the entire guidance system of the missile.

Direct tests of the computer are made with the Monitoring Panel. The intelligence converter is first tested using the beam simulator, as a signal source, then the intelligence converter is fed a signal from the MP to provide tests of the computer. Tests are made of the following: capture sensitivity, floating limiters, (at 10 seconds, 22 seconds and during intercept phase), altitude correction, fixed limiter, dynamic guidance sensitivity, and integral response.

Location: Computer Chassis, Guidance Package, Forward Guidance Section, Quadrant III and IV.

References:

Operation & Description	OP 1956		p. 29
		Fig. 2-10	p. 30
			pp. 36-44
		Fig. 5-18	p. 189
		Fig. 5-20	p. 190
			pp. 199-202
			p. 206
	Term IV Notes		
	Guidance Package		
	General Sec. 1.2.1		
	4		
	Special Secs. 6		
	7		
	8		
	10		
	11		
	12		
	13		
Tests	OP 1956		pp. 150-153 pp. 172-175
	OD 8495		pp. 38-40
	Convair TEM-101-D		

3.1 ISOLATING AMPLIFIER

(Computer "A" Channel, "B" Channel is Identical)

Function: To provide a signal, at the telemetering output which is equal to the "A" channel intelligence converter output. The amplifier (unity gain) assures that the error signal is not modified by circuit loading imposed as a result of telemetering or circuit checks.

Input: D-C from the intelligence converter, the amplitude and polarity of which is determined by the position of the missile in the guidance beam.

Operation: Identical with the compensated d-c amplifier (see par. 3.3). The amplifier gain is made unity by selection of resistors in an attenuator which serves as the input.

Output: D-C signal of same magnitude (reversed polarity) as that of the intelligence converter output.

Principles: Compensation of d-c amplifiers.

Tests: Indirect with Monitoring Panel. Correct operation is implied if intelligence converter test is satisfactory.

Location: Programmer Chassis, Guidance Package, Forward Guidance Section, Quadrant III and IV.

References:

Operation & Description	OP 1956	Fig. 2-5	p. 23
			p. 37
		Fig. 3-20	p. 83
			p. 97
		Fig. 3-31	p. 98
Tests	OP 1956		p. 172
	OD 8495		p. 35

3.2 CORRECTIVE NETWORK AND FILTER

(Computer "A" Channel, "B" Channel is Identical)

Function: To provide noise filtering at the output of the phase comparator and to correct for phase lags in the servo system and time lags in the missile airframe response.

Input: Pulsating d-c from the "A" phase comparator the polarity and amplitude of which is determined by the missile position with reference to the cone center.

Operation: A 0.5 microfarad condenser from the phase comparator to ground supplies the noise filtering. The remainder of the network provides the necessary lead to correct for the lag introduced by this condenser as well as the other lags in the system.

Output: A filtered and corrected version of input signal. Feeds to compensated d-c amplifier.

Principles: A-C networks.

Tests: Indirect, with the Monitoring Panel. Correct dynamic guidance sensitivity implies proper functioning of the corrective network.

Location: Computer Chassis, Guidance Package, Forward Guidance Section, Quadrant III and IV.

References:

Operation & Description	OP 1956	Fig. 2-4	p. 22
	OP 1956		p. 30
	OP 1956		p. 37
	Term IV Notes		
	Guidance Package		
	General Sec. 4		
	Special Secs. 6.3.1		
	7		
Tests	OP 1956		p. 173
	OD 8495		p. 39

3.3 COMPENSATED D-C AMPLIFIER

(Computer "A" Channel, "B" Channel is Identical)

Function: To compensate for the attenuation of the intelligence converter signal which results from the effect of the corrective network. The amplifier introduces a nominal gain of 27 which is then attenuated to fix the over-all gain to 21.4.

Input: D-C voltage from the "A" channel corrective network, the polarity and magnitude of which is determined by the missile position in the guidance beam.

Operation: The amplifier consists of two triodes (in the same envelope) connected in series. The plate load of one is the cathode resistance and r_p of the second, which has its plate connected to B+ (in this case to ground). Analysis of this circuit shows that (for the case when both cathode resistors are equal) the output voltage is

$$e_o = \frac{E_b+}{2} - \frac{Mu(e_g)}{2}$$

where E_b+ is the plate supply voltage and e_g the input signal to the amplifier. Thus the gain Mu/2. A variation in the filament voltage will produce the equivalent change in the cathode to grid voltage for each tube but no change in e_o since the change in apparent grid cathode voltage will be symmetrical in the two series tubes. Slight variations in the emission characteristics of the two cathodes may be corrected by adjustment of one of the cathode resistors. This introduces a slight change in the gain (it is no longer Mu/2) but the deviation resulting is usually less than 5%.

The nominal gain of the amplifier is 27, but a gain setting network having an average gain of .795 is used to provide a standard gain of 21.4 to the input of the gain change network.

Principles: Compensated d-c amplifier.

Tests: Indirect with Flight Ready Indicator and Monitoring Panel. See computer tests. Correct functioning of computer implies correct functioning of the compensated amplifier.

Location: Computer Chassis, Guidance Package, Forward Guidance Section, Quadrant III and IV.

References:

Operation & Description	OP 1956	Fig. 2-4	p. 22
		Fig. 2-10	p. 30
			p. 37
	Term IV Notes		
	Guidance Package		
	General Sec. 4		
	Special Secs. 6.3.2		
	7.3		
Tests	OP 1956		p. 173
	OD 8495		p. 38

3.4 FIRST LIMITER

(Computer "A" Channel, "B" Channel is Identical)

Function: To limit the voltage swing of the compensated amplifier output to 18.8 volts either side of the zero signal d-c level of approximately -105 volts. This limiting is necessary to prevent maneuvering drag and high acceleration which would result from radar beam jitter.

Input: D-C from the output of the compensated amplifier gain setting network. The amplitude of the d-c on either side of a -105 volt zero signal level being determined by the amplitude and polarity of the "A" channel error signal.

Operation: A relatively low impedance voltage divider network is used to set the d-c conduction level of a pair of diodes. One diode has its plate connected to the output point of the gain setting network, the other has the cathode connected to this point. The cathode of the first tube is connected to a point on the voltage divider string which is +18.8 volts with respect to the -105 volt reference level. Thus if the signal at the output of the gain setting network becomes greater than -86.2 volts the diode will conduct and, in effect, tie the amplifier output to the -86.2 volt point of the voltage divider. The low impedance divider will maintain this voltage for any possible signal output level which the amplifier is capable of.

Identical limiting takes place at -123.8 volts thru the action of the other diode. Symmetry of limiting and constancy of level is assured by using precision resistors for the larger values in the divider string.

Output: Varying d-c signal limited to swing between -86.2 and -123.8 volts. Within these limits amplitude and variation from -105 volt zero level determined by missile position in guidance beam.

Principles: Diode limiter action.

Tests: Indirect with Flight Ready Indicator and with Monitoring Panel. In the computer test the floating limits are checked at timer positions of 10 and 22 seconds and after intercept time. Correct values of wing deflection imply proper functioning of floating limits and the succeeding circuitry.

Location: Computer Chasis, Guidance Package, Forward Guidance Section, Quadrant III and IV.

References:

Operation & Description	OP 1956	Fig. 2-4	p. 22
		2-10	p. 30
			p. 38
	Term IV Notes		
	Guidance Package		
	General Sec. 4		
	Special Sec. 8		
Tests	OP 1956		p. 173
	OD 8495		p. 38

3.5 GAIN CHANGE NETWORK

(Computer "A" Channel, "B" Channel is Identical)

Function: To provide a means of changing the voltage division ratio and thus the voltage applied to the input of the integrating amplifier. This is necessary to partially compensate for the capture-guidance beam modulation ratio, to modify the limiter to prevent overcontrol during the first stages of flight, and to provide an increase in missile maneuverability prior to target interception.

Input: Output of the compensated d-c amplifier as modified by the first limiter.

Operation: The entire operation of this network is switch and relay controlled. The switches and relays actuate shunts which change the attenuation of the signal fed to the input of the integrating amplifier. The initial gain of the network is .564. This is changed at +6 seconds (by the actuator of the capture relay) to .121. The gain remains at .121 for 18 seconds at which time the programmer (by means of switch H) changes the gain to .181. The network gain remains constant at this value until the time to intercept relay closes. The closing of this relay changes the gain to .240. The time to intercept relay is operated by a tube which is biased beyond cutoff by a negative voltage applied to a condenser. The voltage is obtained from the radar range computer and is applied through the backscratcher. When this voltage is removed the condenser discharges (RC = 66 sec.) until the tube conducts, closing the relay. The relay also actuates the warhead fuze.

Output: A d-c signal, whose magnitude of variation from the zero signal level is determined by the missile error and by the modifications introduced by the network itself.

Principles: Voltage dividers.

Tests: Indirect with Flight Ready Indicator and Monitoring Panel. See tests of computer and floating limits.

Location: Programmer Chassis, Guidance Package, Forward Guidance Section, Quadrant III and IV.

References:

Operation & Description	OP 1956	Fig. 2-5	p. 23
		Fig. 2-10	p. 30
			p. 38
		Fig. 2-13	p. 43
	Term IV Notes		
	Guidance Package		
	General Sec. 1.3		
	Special Secs. 6.3.4		
	8		
	10		
Tests	OP 1956		p. 173
	OD 8495		p. 38

3.6 INTEGRATING AMPLIFIER

(Computer "A" Channel, "B" Channel is Identical)

Function: To average the widely varying radar signal in order to determine the proper average wing signal and to modify this average in order to reduce tendency of the missile to oscillate about the cone center.

Input: D-C signal output from the gain change network.

Operation: The integrating amplifier consists of two sections in a regenerative feedback circuit. The first section is a voltage amplifier with a gain of 2.5. The second is a cathode follower feedback network which feeds a portion of the output signal of the first section back to the input so that it effectively adds to the input signal. The effect of the feedback section is to increase the overall gain of the amplifier at a rate which is a linear function of both the amplitude of the impressed error signal and its duration. The relationship between output voltage, input voltage and time is

$$E_{out} = 2.5\, E_{in} + .687\, E_{in} T$$

The output is grounded until 0.5 seconds after separation, at which time switch F is opened by the programmer, ungrounding the integrator.

<u>Output</u>: D-C voltage with zero signal reference level at ground, the swing to either side of ground is determined by the error of the missile from cone center.

<u>Principles</u>: D-C amplification, regenerative feedback, cathode followers.

<u>Tests</u>: Direct with Monitoring Panel. Reference and error signals are applied to the intelligence converter; the integrator is ungrounded and the wing rates measured. Since all the other components of the computer, and the wing servos, have been previously checked this provides a direct test of the integrating amplifier.

<u>Location</u>: Computer Chassis, Guidance Package, Forward Guidance Section, Quadrant III and IV.

<u>References</u>:

Operation & Description	OP 1956	Fig. 2-4	p. 22
		2-10	p. 30
			p. 39
	Term IV Notes		
	Guidance Package		
	General Sec. 4		
	Special Sec. 11		
Tests	OP 1956	Paragraph 5-14	p. 174
	OD 8495		p. 39-40

3.7 FIXED LIMITER

(Computer "A" Channel, "B" Channel is Identical)

Function: To limit the output of the integrating amplifier to ± 13.7 volts.

Input: The output of the integrating amplifier drives a voltage divider network. One point of this voltage divider string is attached to a set of limiting diodes which are designed to limit this point to a 13.7 volt swing on either side of ground. For the case of a large, rapid increase in missile error this fixed limit will clip the swing of the amplifier first. (For smaller, continued errors the integral limiter will limit first, see par. 3.8). The operation of the limiter is similar to that discussed for the first limiter. Somewhat farther down on this voltage divider string is the connection to the cathode follower which provides the output to the next stage.

Output: D-C output of the integrating amplifier limited to ± 13.7 volt swing.

Principles: Diode limiter action.

Tests: Direct with Monitoring Panel. Wing angles are read with integrator ungrounded and a steady error signal. Correct value of wing angle indicates correct fixed limiter performance.

Location: Computer Chassis, Guidance Package, Forward Guidance Section, Quadrant III and IV.

References:

Operation & Description	OP 1956	Fig. 2-4	p. 22
		2-10	p. 30
			p. 41
	Term IV Notes		
	Guidance Package		
	General Sec. 4		
	Special Sec. 12.2		
Tests	OP 1956	Paragraph 5-13	p. 173
	OD 8495		p. 39

3.8 INTEGRAL LIMITER

(Computer "A" Channel, "B" Channel is Identical)

Function: To limit regeneration in the integrating amplifier.

Input: The integrated signal applied to the grid of the first cathode follower in the integrating amplifier feedback loop.

Operation: The maximum voltage across the integrating condenser of the integrating amplifier feedback loop is limited to ± 13.7 volts by a pair of limiting diodes. These diodes act in a manner identical to the fixed limit and floating limit diodes and in fact use the same voltage divider as the fixed limit diodes.

Output: None to the succeeding stages. However, the effect of the limiter is to limit the output of the integrating amplifier to ± 13.7 volts for those signals which are so small and of such duration as to result in a large regenerative signal and little directly amplified output.

Principles: Diode limiter action.

Tests: Direct with Monitoring Panel. The integral response checks provide direct evidence of proper integral limiting.

Location: Computer Chassis, Guidance Package, Forward Guidance Section, Quadrant III and IV.

References:

Operation & Description	OP 1956	Fig. 2-4	p. 22
		2-10	p. 30
			p. 41
	Term IV Notes		
	Guidance Package		
	General Sec. 4		
	Special Sec. 12.1		
Tests	OP 1956		p. 173
	OD 8495		pp. 39-40

3.9 CATHODE FOLLOWER OUTPUT

(Computer "A" Channel, "B" Channel is Identical)

Function: To provide a power source of low output impedance to the inverse pressure potentiometer.

Input: D-C output of the integrating amplifier as modified by the fixed and integral limiters.

Operation: A low impedance output is desirable since it not only helps reduce stray inductive and capactive pickup in the relatively long line from the computer to the warhead (where the inverse pressure pickoff is housed) but also allows the inverse pressure pickoff potentiometer to be so chosen as to allow it to present a low output impedance to the following $f_2(t)$ pickoff.

The operation of the cathode follower is standard in all respects. An adjust potentiometer is included in the cathode resistor to allow setting of the d-c zero signal level.

Output: D-C output of the integrating amplifier as modified by limiters. Output goes to inverse pressure pickoff in warhead.

Principles: Cathode followers.

Tests: Indirect with Flight Ready Indicator and Monitoring Panel. Proper functioning of computer section implies correct operation of cathode follower.

Location: Computer Chassis, Guidance Package, Forward Guidance Section, Quadrant III and IV

References:

Operation & Description	OP 1956	Fig. 2-4	p. 22
		2-10	p. 30
			p. 42
	Term IV Notes		
	Guidance Package		
	General Sec. 4		
	Special Sec. 13		
Tests	OP 1956		p. 173
	OD 8495		p. 38

3.10 INVERSE PRESSURE (1/Ps) POTENTIOMETER
$f_2(t)$ POTENTIOMETER

(Computer "A" Channel, "B" Channel is Identical)

Function: (1) To provide an increase of gain with increasing altitude in order to compensate for loss in wing effectiveness as the air density decreases.
(2) To provide gain changes which compensate for changes in Mach number, center of gravity and weight during the missile flight.

Input: D-C from the cathode follower output stage of the integrating amplifier and accompanying limiters. The polarity and magnitude of the signal is determined by the direction and distance of the missile from the center of the cone.

Operation: The signal from the cathode follower is applied to a potentiometer placed in the missile nose assembly. The wiper of the potentiometer is connected to an aneroid bellows which increases the pickoff voltage as the pressure decreases. The gain of this circuit is 0.45 at sea level, 0.66 at 10,000 feet and 1.0 at 20,000 feet. The pickoff signal is then returned to the computer and applied to the $f_2(t)$ potentiometer the wiper of which is driven by the programmer. The operation is similar to that of the programmer position potentiometer. (See par. 6.1 and 6.3.)

Output: D-C of polarity and magnitude determined by missile position relative to cone center and of proper magnitude to drive the servo amplifier.

Principles: Potentiometers (cylindrical type), operation of aneroid bellows.

Test: Altitude correction is not tested with Flight Ready Indicator or Monitoring Panel. Continuity of altitude potentiometer may be inferred if computer checks are satisfactory on these instruments. Simulated altitude checks are made with the Monitoring Panel but these are not made by actual variation of the altitude potentiometer wiper position. Indirect tests of the $f_2(t)$ correction are made as part of the computer tests by both the Flight Ready Indicator and Monitoring Panel.

Location: Inverse pressure potentiometer in nose assembly; $f_2(t)$ potentiometer on programmer chassis in guidance package; Forward Guidance Section, Quadrant III and IV.

References

Operation & Description	OP 1956	Fig. 2-4	p. 22	
		2-10	p. 30	
			p. 31	
		Fig. 2-11 2-12,	p. 35	
			p. 36	
	Term IV Notes			
	Guidance Package			
	General Secs. 1.3			
	4			
	Special Secs. 9.1			
	9.2.1			
	13			
Tests	OP 1956		p. 129	
			p. 173	
	OD 8495		pp. 10, 39	

3.11 SERVO AMPLIFIER

("A" Channel, "B" Channel is Identical)

Function: To convert the d-c output of the computer to a precisely proportional control surface deflection.

Input: D-C of polarity and magnitude determined by the missile position in the cone and the operations performed by the computer.

Operation: The servo system consists of the servo amplifiers, the hydraulic valve operated by a differential solenoid and a feedback potentiometer with the wiper attached to the control surface. The servo amplifier has two stages, a difference amplifier first, followed by a direct coupled power amplifier stage. One side of the difference amplifier is driven by the d-c signal from the computer, the other side by a signal from the feedback potentiometer attached to the wing. This potentiometer is placed across the +200 to -200 v

lines in such a manner that the center is approximately ground (which is the zero error signal level of the computer output). A trim adjustment permits exact balance of this voltage to ground for zero wing angle when no error signal is present. If an error is present the difference amplifier will produce an unbalanced condition in the two power amplifiers; this will produce an unbalanced current in the differential solenoid. The solenoid will open the hydraulic valve driving the wing actuator until the feedback voltage (proportional to wing position) matches the input from the computer. When this point is reached the power amplifiers will again receive balanced drive voltages and thus the differential solenoid will return the valve to the closed position.

Output: Push-pull d-c drive to the differential solenoid of the control surface actuator.

Principles: Difference amplifiers, power amplifiers, differential solenoids, feedback.

Test: Indirect with the Flight Ready Indicator, as part of the over-all missile test. Direct with the Monitoring Panel, as d-c step signal is applied to the difference amplifier input (after the trim adjustment is made) and both the wing deflection rate and sense are checked.

Location: Servo Amplifier Chassis, Guidance Package, Forward Guidance Section, Quadrant III and IV.

References:

Operation & Description	OP 1956	Fig. 2-14	p. 43
			p. 44
		Fig. 2-15	p. 46
			p. 48
	Term IV Notes		
	Guidance Package		
	General Secs. 1.2.1		
	Special Sec. 18		
Tests	OP 1956		p. 173
	OD 8495		p. 37

ROLL STABILIZATION SYSTEM

4. Roll Stabilization System
    - 4.1 Free Gyro and Synchro System
    - 4.2 Missile Roll Corrector
    - 4.3 Altitude Compensating Circuit
    - 4.4 Gain Change Amplifier
    - 4.5 Phase Detector
    - 4.6 Derivative (Rate) Network
    - 4.7 Compensated D-C Amplifier
    - 4.8 Roll Servo Amplifier

4. ROLL STABILIZATION SYSTEM

Function: To bring the missile to the proper roll attitude immediately after launching and to maintain that position by moving the rollerons in a manner to oppose the rolling moments applied by the wings.

Input: 400 cps signal amplitude modulated by crosslevel angle information from shipboard computer (prior to launching).

Operation: A free gyro on the missile maintains a horizontal reference in space. An associated synchro system changes relative roll position into an electrical signal which after being amplified, compensated for altitude, rate, and distance from launcher, is demodulated and introduced to the roll servo system as a d-c signal whose amplitude is proportional to roll error. A solenoid operated valve in the servo system controls movement of the rollerons.

Output: Roll control motion of rollerons.

Tests: Monitoring Panel Checks:

Roll sensitivity, balance and trip check
Servo amp. dynamic test
Wing speed check
Roll rate test
Roll corrector test
Roll input signal monitored by recorder and VTVM
Gyro output monitored by VTVM

Flight Ready Indicator Checks:

Rolleron trims
Demodulator balance
Roll gain during boost
Roll guidance signal sense

Location: Free gyro and pick off synchro: forward guidance section, Quadrant III; Servo circuits: servo chassis, guidance package, forward guidance section, Quadrant III and IV; Roll amplifiers, demodulator, gain change, rate network, compensated d-c amplifier: programmer chassis, guidance package, forward guidance section, Quadrant III and IV; Inverse pressure potentiometer: nose assembly; Hydraulic valve, roll actuator, feedback potentiometer: aft guidance section, Quadrant III and IV.

References:

Block Diagram	OP 1956	pp. 52-3
Operation & Description	Term IV Notes Guidance Sec. 6 & 7	
	OP 1956	p. 49-59
Tests	OP 1956	pp. 152 & 176
	OD 8495	pp. 9, 17, 19, 20, 21, 34, 35

4.1 FREE GYRO AND SYNCHRO SYSTEM

Function: To transform deck cross level information (before launching missile) and roll attitude information (after flight has begun) into an electrical signal.

Input: 400 cps signal, amplitude modulated by deck cross level information from shipboard computer (prior to launching).

Operation: The rotor of a synchro transformer is mechanically coupled to a free gyro which maintains a vertical reference in space. The stator is connected to the missile frame. The synchro transformer is associated with a synchro generator whose rotor is excited by a 26 v, 400 cps, a-c power supply. The missile is launched in a roll position 67 1/2° away from normal roll attitude for reasons connected with the launcher's mechanical design. To correct for this, the gyro is caged in a position 67 1/2° away from normal roll attitude. This causes a 67 1/2° error signal to appear across the rotor of the synchro transformer, which feeds into the roll computer. Before launching, the synchro generator acts as a motor and receives deck cross level information from a synchro generator in the Shipboard Roll Corrector. As the missile is launched the rotor of the synchro generator is locked, thereby capturing the last order from the Shipboard Roll Corrector, and this order is transmitted to the control transformer. At the same time, the gyro is uncaged and the instantaneous relative positions of the control transformer rotor with respect to the generator rotor cause an error signal to appear at the control transformer rotor terminals. At the instant of launching this signal represents an error of 67 1/2° $\pm$ the error angle stored in the generator.

Output: 400 cps a-c whose rms value is proportional to roll error and whose phase is either 0° or 180° from exciting voltage, depending upon direction of roll error. The output is fed through the altitude compensating network to the roll amplifiers.

Principles: With normal connections between stators, the output of a control transformer is proportional in magnitude to the relative angular position of its rotor with respect to the rotor of an associated synchro generator. When the angular difference is 90°, the signal is zero.

Tests: Output signal monitored by Monitoring Panel VTVM. Indirectly tested by Monitoring Panel Roll sensitivity and Balance checks, and Roll Corrector test and Flight Ready Indicator check.

Location: Forward Guidance Section, Quadrant III and IV.

References

Description	Term IV Notes Guidance Sec.	p. 6
	OP 1956	pp. 49-52
Picture	OP 1956	p. 191
Test	OP 1956	p. 152
	OD 8495	pp. 10, 19, 34

4.3 ALTITUDE COMPENSATING CIRCUIT

Function: To vary the amplitude of the roll position signal directly with missile altitude.

Input: 400 cps modulated signal from the free gyro control transformer.

Operation: The wiper of a potentiometer is connected to a sylphon bellows. As higher altitudes are attained the pressure on the bellows drops and the wiper of the potentiometer moves in a direction to increase the output of the potentiometer.

Output: Same as input but voltage attenuated. Feeds into gain change amplifier.

Principles: Atmospheric pressure varies with altitude. Distance between end plates of a sylphon bellows varies with ambient pressure. Therefore changes in altitude cause relative motion of the bellows end plates, i.e., a mechanical signal proportional to altitude.

Tests: No direct test for this component. Indirectly checked by Flight Ready Indicator.

Location: Nose assembly

References:

Description	OP 1956	pp. 55, 56
Test	OP 1956	p. 125

4.2 MISSILE ROLL CORRECTOR

Function: To introduce to the missile roll stabilization system information concerning the cross level angle of the ship's deck at the instant of launching.

Input: A mechanical rotation of the ships roll corrector synchro generator which is proportional to changes in the ship's deck cross level angle.

Operation: The ship board free gyro transmits the cross level angle to the shipboard computer. This angle is here multiplied by the secant of the angle between the launcher and the horizon, and is introduced to the shipboard roll corrector as an angular position of its synchro generator rotor. The stator windings are parallel connected to the stator terminals of the missile's synchros, while the rotor is excited by 26 v 400 cps a-c and connected in series with the missile's synchro generator rotor. Prior to launching the latter synchro acts as a motor and its rotor follows exactly the motion of the rotor in the shipboard synchro. At the time of launching, the (electrical) connections between the missile and the ship are broken and a solenoid locks the rotor of the missile's synchro generator. Thus the order from the Ship's Roll Corrector at the exact time of launching is captured and held.

Output: An angular rotor position proportional to a function of the ship's deck cross level angle. This rotor position induces an error voltage in the gyro pickoff synchro (control transformer see sec. 4.1).

Principles: The rotor of a synchro generator induces a voltage in the stator windings which is proportional in magnitude to the angular position of the rotor.

Tests: Directly by Monitoring Panel Roll Corrector test. Indirect check by Flight Ready Indicator.

Location: Forward Guidance Section, Quadrant III and IV.

References:

Description	OP 1956	p. 50
Test	OP 1956	p. 125
	OD 8495	pp. 10, 19, 21, 34, 35

4.4 GAIN CHANGE AMPLIFIER

Function: To reduce the amplitude of the roll error signal immediately after booster separation and for the period necessary for the missile to roll to its zero reference position. This damps out roll overshoot.

Input: 400 cps modulated signal from altitude compensating network. Impulse to relay from programmer 0.5 seconds after booster separation.

Operation: At the time of booster separation the input resistance network to the amplifier grid is shunted by a condenser in series with the vacuum tube gain changer. With the gain changer tube conducting, the impedance of this circuit is low and shunts a portion of the error signal to ground. After a period of .5 seconds the programmer opens a switch in the grid circuit of the gain changer and a condenser is charged, causing the grid to go more negative and finally to cut-off. With the tube cut-off (one second after booster separation), the impedance of the tube and series capacitor is high and negligible signal is shunted away from the amplifier grid. The error signal after amplification is introduced to the input transformer of the phase comparator.

Output: 400 cps modulated with roll error signal to the phase comparator.

Principles: The plate impedance of a triode vacuum tube varies inversely with grid bias voltage.

Test: No direct test. Indirectly checked by following Monitoring Panel tests: Roll system sensitivity check, Roll rate change test. Indirectly checked by Flight Ready Indicator.

Location: Programmer Chassis, Guidance Package, Forward Guidance Section, Quadrant III and IV.

References:

Description	OP 1956	p. 56
Test	OP 1956	p. 125
	OD 8495	pp. 9, 10, 34, 35

4.5 PHASE DETECTOR

Function: To demodulate the roll error signal since a d-c servo system is used to actuate the rollerons. The detector not only rectifies the signal but changes the polarity of its output to correspond to the direction of roll error.

Input: 400 cps amplitude modulated with the roll error signal. The phase of the carrier wave is either 0° or 180° from the synchro generator exciting voltage.

Operation: The error signal is fed through a transformer to the input terminals of a ring demodular consisting of four diodes. The remaining two terminals of the demodulator are fed (from a transformer) a 400 cps constant amplitude reference voltage which is in phase with the synchro generator's exciting voltage and of amplitude about twice maximum error signal. The demodulated signal is taken from the center taps of the two input transformers. (See section 2.4 for further discussion of the operation of this circuit.)

Output: D-C signal whose magnitude varies with angle of roll error and whose polarity changes with direction of roll error. Output fed to rate network.

Principles: Network theory, superposition, Kirchoff's laws and rectification.

Tests: No direct tests. Indirect tests same as gain change amplifier.

Location: Programmer Chassis, Guidance Package, Forward Guidance Section, Quadrant III and IV.

References:

Description	OP 1956	p. 57
Test	OP 1956	p. 125
	OD 8495	pp. 9, 10, 34, 35

4.6 DERIVATIVE (RATE) NETWORK

Function: To introduce a rate correction when the input is varying.

Input: Varying d-c signal from the phase detector.

Operation: This resistor-condenser network introduces a damping effect on the signal to prevent oscillation of the missile around its roll zero attitude. Rate correction leads the steady state signal and opposes the direction of missile roll. The frequency response curve of this network peaks at 50 cps and has a leading angle on the low frequency side. This phase angle is a maximum of about 50° at 15 cps falling off on both sides of this frequency.

Output: A corrected, varying d-c signal into a compensated d-c amplifier.

Principles: RC networks.

Tests: No direct test. Correct operation of roll system indicates that corrective network is operating satisfactorily.

Location: Programmer Chassis, Guidance Package, Forward Guidance Section, Quadrant III and IV.

References:

Description	Term IV Notes Guidance Package Sec. 7	
	OP 1956	p. 58

4.7 COMPENSATED D-C AMPLIFIER

Function: To amplify the roll error signal which has been attenuated by the derivitive network.

Input: Varying amplitude d-c error signal from derivitive network.

Operation: See sec. 3.3 which describes an identical amplifier.

Output: Amplified d-c error signal to input roll servo amplifier.

Principles: Compensated d-c amplifier theory.

Test: No direct tests. Indirect tests same as gain change amplifier.

Location: Programmer Chassis, Guidance Package, Forward Guidance Section, Quadrant III and IV.

References:

See sec. 3.3.

4.8 ROLL SERVO AMPLIFIER

Function: To increase the roll error signal to a power level sufficient to operate the solenoid actuated transfer valve.

Input: Roll error, a varying d-c signal from the rate network.

Operation: The servo system consists of the servo amplifiers, the hydraulic valve operated by a differential solenoid and a feed-back potentiometer with the wiper attached to the control surface. The servo amplifier has two stages, a difference amplifier first, followed by a direct coupled power amplifier stage. One side of the difference amplifier is driven by the d-c signal from the computer, the other side by a signal from the feedback potentiometer attached to the wing. This potentiometer is placed across the +200 to -200 v lines in such a manner that the center is approximately ground. A trim adjustment permits exact balance of this voltage to ground for zero wing angle when no error signal is present. If an error is present the difference amplifier will produce an unbalanced condition in the two power amplifiers, this will produce an unbalanced current

in the differential solenoid. The solenoid will open the hydraulic valve driving the wing actuator until the feedback voltage matches the input from the computer. When this point is reached the power amplifiers will again receive balanced drive voltages and thus the differential solenoid will return the valve to the closed position.

Output: Push-pull d-c drive to the differential solenoid of the roll control surface actuator.

Principles: Difference amplifier, power amplifier, differential solenoids, feedback.

Test: Indirect with Flight Ready Indicator. Direct with the Monitoring Panel.

Location: Programmer Chassis, Guidance Package, Forward Guidance Section, Quadrant III and IV.

References:

Operation	OP 1956	p. 59
	Term IV Notes	
	Guidance Package Sec. 1 & 18	
Test	OD 8495	p. 37

ELECTRICAL SYSTEM

5.1 Power Supply

- 5.1.1 Alternator
- 5.1.2 -200 Volt Regulated Supply
- 5.1.3 +200 Volt Regulated Supply
- 5.1.4 Local Oscillator Regulated Supply
- 5.1.5 Low Voltage Supply

5.2 Power Changeover System

5.3 Booster Firing System

5.1 POWER SUPPLY

Function: To supply all necessary a-c and d-c voltages for operation of the missile guidance components.

Input: Mechanical power from a hydraulic turbine to drive the alternator at a constant speed of 12,136 RPM.

Operation: A hydraulic turbine drives a 3 phase a-c induction alternator which delivers 115 v at a frequency of 400 cps. This voltage is transformed to appropriate magnitudes to drive a single phase -200 v, regulated, d-c power supply; a double winding 3 phase +200 v regulated, d-c power supply; and a 3 phase low voltage d-c and a-c supply. The high voltage supplies consist of vacuum tube rectifiers delivering filtered outputs to series type vacuum tube voltage regulators. The low voltage d-c supply consists of an unregulated 3 phase full-wave dry-disc rectifier unit.

Output: -200 v d-c ± 2 v at 75 ma to missile -200 v Bus.

+200 v d-c ± 2 v at 320 ma to missile +200 v Bus.

+280 v d-c ± 2 v at 30 ma for local oscillator power supply.

+370 v d-c unregulated at 500 ma to servo amplifiers.

+30 v d-c at 3 amps for relay operation.

24 v 3 phase a-c 400 cps for operation of gyro motors.

Principles: The series type voltage regulators operate on the principle that a three element vacuum tube has a plate impedance which varies with impressed grid voltage. As the voltage output of the supply changes with respect to a reference voltage, the difference voltage is amplified and applied to the grids of the series regulator tubes. The plate impedance of these tubes is changed in the direction required to cause a change in the series voltage drop which reduces the difference voltage.

Tests: Monitoring Panel Checks

(1) Alternator Output Voltage (indication and recording)

(2) Alternator Phase Sequence

(3) Alternator Frequency

(4) +200 v Bus

(5) -200 v Bus

(6) Difference Voltage

(7) 26 v a-c Output

(8) +30 v d-c Output

(9) Filament Transformer

Flight Ready Indicator gives indirect indication on regulated voltages.

Location: Power Supply Package, Forward Guidance Section, Quadrant I.

References:

Block Diagram	OP 1956	p. 77
Circuit Diagram	OP 1956	pp. 80, 182, 183
Schematic (Air and Hydraulic Components)	OP 1955	p. 20
Photograph of Power Supply Components (Non-electronic)	OP 1955	p. 21
Pictures		p. 194
Block Diagram	Term IV Notes Electrical System Sec. 1	
Parts List	Term IV Notes Electrical System Sec. 3	
Test	OP 1956	pp. 126, 130
	OD 8495	p. 32-33

5.1.1 ALTERNATOR

Function: Primary electric power generator. Provides 115 v to neutral, 3 phase at 400 cps.

Input: Mechanical power from hydraulic turbine at constant speed of 12,136 RPM.

Operation: The rotor which is mechanically driven, is a conventional induction squirrel cage with laminated steel spiders and aluminum bars representing four field poles. The stator coils are arranged 3 phase wye connected supplying four output terminals. An excitation capacitor is shunted across each phase so that rated current may be drawn. Voltage regulation is accomplished by regulating turbine speed since the magnetic circuit is designed to operate in the saturated portion of its B-H curve.

Output: 3 phase, 115 v to neutral, 400 cps; rated at 770 watts, to missile transformer bank. Voltage regulation 4.5%.

Application:

Note: The induction generator is used very rarely as a power source since its efficiency and power factor are always poor while at the same time it is difficult to control frequency with variable load. In this application the severe space limitations dictate an extremely high speed of operation and the squirrel cage construction is the only one presently rugged enough to suit the purpose.

Principles: Residual magnetic flux is cut by the rotor bars building up a revolving magnetic field. This field cutting the stator conductors induces the output voltage.

Tests: Monitoring panel checks alternator output voltages (indication and recording), phase sequence and frequency. Operation tested indirectly by Flight Ready Indicator.

Location: Forward Guidance Section, Quadrant II.

References:

Description	OP 1956	p. 76-78
Operation	Term IV Notes Electrical System Sec. 3	
Test	OD 8495	p. 32-33

5.1.2 -200 VOLT REGULATED SUPPLY

Function: To supply a regulated -200 volts to components requiring it for their operation.

Input: 115 v, 1 phase, 400 cps a-c.

Operation: The input voltage is transformed to approximately 400 v, rectified, filtered and applied to the plates of a pair of parallel connected, triode, series regulators. The negative side of the rectifier circuit is connected to a regulated +170 v from the +200 volt supply through a resistance network. A tap from this network biases the grid of the first of a pair of cascaded triode amplifiers whose output controls the grid of the series voltage regulators. If the output voltage varies from -200 v, the difference voltage is amplified and applied to the grids of the series regulators. The plate impedance of these tubes is changed in a manner which brings the output voltage to its rated value.

Output: -200 v d-c regulated to ± 2 v, to missile -200 v Bus.

Principles: The plate impedance of a triode varies inversely as the impressed grid voltage.

Tests: Monitoring Panel checks, output voltage and difference voltage.

Location: Power Supply Package, Forward Guidance Section, Quadrant I.

References:

Description	OP 1956	p. 79
Operation	Term IV Notes Electrical System Sec. 3.2	
Block Diagram	Term IV Notes Electrical System Sec. 3.6	
Circuit Diagram	Term IV Notes Electrical System Sec. 3.6	
Test	OD 8495	p. 32-33

.5.1.3 +200 VOLT REGULATED SUPPLY

Function: To supply a regulated +200 volts to components requiring it for their operation.

Input: 115 v, 3 phase 400 cps a-c.

Operation: The input voltage is transformed to approximately 400 volts. It is rectified, filtered, and applied to the plates of three parallel connected triodes acting as series regulating impedances. The +200 v output is connected to the -200 v output (which is also regulated) through a resistance network. The voltage from a tap on this string is amplified in three stages and applied to the grids of the regulating tubes. Should the +200 v output vary with respect to the -200 v supply, the impedance of the series regulating tubes will change to bring the output voltage back to rated value.

Output: +200 v d-c regulated to ± 2 v and following -200 v supply within ±0.2 v, to missile +200 v Bus.

Principles: Plate impedance of triode vacuum tube varies inversely with impressed grid voltage.

Tests: Monitoring Panel checks output voltage and difference voltage.

Location: Power Supply Package, Forward Guidance Section, Quadrant I.

References:

Description	OP 1956	p. 79
Operation	Term IV Notes Electrical System Sec. 3.2.4	
Test	OD 8495	pp. 32-33

5.1.4 LOCAL OSCILLATOR REGULATED SUPPLY

Function: To supply plate bias to the local oscillator.

Input: +370 v d-c.

Operation: The input is applied to the plate of a triode connected series voltage regulator tube. The output is connected to the -200 v output through a resistor network. A tap from the network applies bias to the grid of a tetrode amplifier whose output controls the grid of the series regulator tube. If the output voltage varies from +280 v the error voltage is amplified and applied to the grid of the regulator tube whose plate impedance is changed in a direction to change the output voltage to its rated value.

Output: +280 v to klystron LO accelerator and -200 v to AFC Phase Comparator.

Principles: The plate impedance of a triode varies inversely as the impressed grid voltage.

Tests: No panel test noted as yet. Indirect test by proper receiver operation.

Location: Regulator Chassis, Power Supply Package, Forward Guidance Section, Quadrant I.

References:

Operation, Circuit — Term IV Notes, Electrical System Sec. 4

5.1.5 LOW VOLTAGE SUPPLY

Function: To supply 30 v d-c for operation of all relays, and solenoids used in missile guidance and 26 v 3 phase 400 cps for operation of the gyro motors.

Input: 115 v, 3 phase, 400 cps a-c.

Operation: The input is transformed to approximately 26 v and is rectified in a three phase full wave rectifier circuit using selenium dry disc rectifiers. No filtering or regulation is provided.

Output: 26 v 3 phase 400 cps a-c to relays and solenoids; 30 v pulsating d-c with ripple frequency of 2400 cps unregulated and unfiltered to roll free gyro motor.

Principles: Transformer action, rectification.

Tests: Monitoring Panel provides check for 26 v a-c and 30 v d-c.

Location: Low Voltage Supply Chassis, Power Supply Package, Forward Guidance Section, Quadrant I.

References:

Description	OP 1956	p. 79
Operation	Term IV Notes Electrical System Sec. 3.4	
Circuit	Term IV Notes Electrical System Sec. 4.3	
Test	OD 8495	pp. 32-33

5.2 POWER CHANGEOVER SYSTEM

Function: To change the electrical supply of the missile from the external supply used during warm up to the internal supply prior to launching and to activate certain guidance components necessary for launching.

Input: 115 v, 3 phase, 400 cps a-c; 115 v, 1 phase, 60 cps a-c; 26 v, 400 cps a-c; +30 v d-c.

Operation: Prior to launching, the 3 phase input is applied through a power changeover relay to the power supply transformer bank. After a two minute period has passed an interlock switch may be closed energizing a relay which causes air to be applied to the autopak and the alternator starts. Alternator output voltage energizes the changeover relay removing the external supply and energizing the missile operate relay. The closing of the latter relay causes the solenoid brake of the roll corrector synchro to lock its rotor, uncages the roll free gyro, and removes the voltage from the gyro caged indicator light on the launcher.

Principles: Relay and switching operation.

Tests: Monitoring Panel recorder provides information on the operation of this circuit.

Location: Power Supply Package, Forward Guidance Section, Quadrant I.

References:

Operation	Term IV Notes Electrical System Sec. 6	
Circuit	Term IV Notes Electrical System Sec. 6	
Test	OD 8495	pp. 21-22

5.3 BOOSTER FIRING SYSTEM

Function: To effect normal launching of the missile and to provide means for jettisoning missile when required.

Input: 115 v, 1 phase, 60 cps.

Operation: As the last firing interlock switch is closed, the uncaging solenoid of the roll free gyro is energized. If all three interlock switches have been thrown correctly, the uncaging solenoid contacts cause a relay to be energized which completes a circuit to the backscratcher latch solenoid. Unlatching the backscratcher latch permits the backscratcher to be separated from the missile by a spring which in turn closes a switch energizing the booster latch solenoid. This releases the booster latch which holds the booster locked to the launching rails. The booster is now free to move on the launching rails. As the booster latch releases it closes a switch which energizes a relay whose contacts apply power to the booster squib through the safety switch and the emergency fire switch. This launches the missile. Two switches are available which permit jettisoning the missile in case normal firing is impossible. The contactor Release Over-ride Switch will energize the backscratcher latch solenoid while the Emergency Fire Switch will apply power to the booster squib.

Principles: Relay and switching operation.

Tests: Monitoring Panel provides check. Firing interlock checked by Flight Ready Indicator (loss of power from Pos. A to Pos. B if gyro does not uncage).

Location: This circuit is distributed over several sections of the missile.

References:

Operation	Term IV Notes Electrical System Sec. 6
Circuit	Term IV Notes Electrical System Sec. 6

PROGRAMMER

6. Programmer

6.1 Position Potentiometer

6.2 $f_1(t)$ Potentiometer

6.3 $f_2(t)$ Potentiometer

6.4 Switch A

6.5 Switch B and B_1

6.6 Switch C

6.7 Switch D and F

6.8 Switch E

6.9 Switch G

6.10 Switch H and I

6.11 Switch J

6. PROGRAMMER

Function: To energize and vary in a predetermined manner circuits which help to determine the characteristic operational pattern of the missile during flight.

Input: Power from 115 volt, 400 cycle alternator supplied through spring-loaded switch closed at separation by lanyard attached to booster.

Operation: Operation of the programmer is initiated by a lanyard attached to the booster. Upon separation, this lanyard withdraws allowing the spring-loaded power switch to close. Closing the switch applies power to a 115 volt, 400 cycle, 11,000 rpm miniature type induction motor. This motor operates thru a gear train to turn a shaft at 1 revolution in 45 seconds. Attached to the shaft are the brushes of 4 cylinder type potentiometers and 11 cams, each of which actuates a single pole double throw switch. One of the switches opens the motor power line at the end of 40 seconds, stopping the programmer shaft at this time. This switch also completes a portion of the re-set circuit, which permits the programmer to be re-set by application of power from an external source.

Output: Discussed below under sections devoted to individual potentiometers and switches.

Test: Indirect with Flight Ready Indicator and Monitoring Panel. Proper timer action is necessary if the missile performance in either of these tests is to be satisfactory. Direct test of programmer is also made with Monitoring Panel.

Location: Programmer Chassis, Guidance Package, Forward Guidance Section, Quadrant III and IV.

References:

Operation and Description	OP 1956		p. 31
		Fig. 2-11, 2-12	p. 35
		Fig. 2-13	p. 43
	Term IV Notes Guidance Package Special Sec. 9		
Tests	OP 1956		p. 179
	OD [illegible]495		p. 33

6.1 POSITION POTENTIOMETER (Programmer)

(NOTE: Features and references common to all four programmer potentiometers are listed here.)

Function: Provides an indication of the position of the programmer for telemetering purposes.

Input: Connected to +200 volts thru 950 K resistor, Since potentiometer is 10 K, this means input is +2.08 volts.

Operation: The constant value d-c input is applied to a resistance element held in a plastic holder. A retaining spring pushes the element and holder against a plastic cylinder. A groove in the plastic cylinder carries a wire which makes contact with the resistance element at only one point at any particular rotational position of the plastic cylinder. The plastic cylinder is turned by the programmer shaft. By properly inscribing the groove on the drum, the output voltage from the potentiometer may be made any desired fraction of the cylinder position (and thus of time).

Output: A linear function of the shaft position varying from 0 to 2.08 volts with timer shaft position.

Principles: Cylindrical type potentiometers.

Tests: Direct with Monitoring Panel. The output voltage is used to drive the programmer position meter which is checked against a clock.

Location: Programmer Chassis, Guidance Package, Forward Guidance Section, Quadrant III and IV.

References:

Operation and Description	OP 1956		p. 31
		Fig. 2-11, 2-12	p. 35
			p. 36
			p. 222
		Fig. A-2	p. 224
	Term IV Notes Guidance Package Special Sec. 9		
Tests	OP 1956		p. 174
	OD 8495		p. 33

6.2 $f_1(t)$ POTENTIOMETER

Function: Compensates for radar beam pattern divergence with range.

Input: Error signal from radar receiver, modified by capture relay effect. (See $f_1(t)$ discussion in Computer section.)

Output: Attenuated error signal to error amplifier, amount of attenuation decreasing with time to correct for angular divergence of radar beam.

Tests: Indirect with Flight Ready Indicator and Monitoring Panel. (See $f_1(t)$ discussion in computer section.)

Principles)
Location:) See Programmer Position Potentiometer.
References:)

6.3 $f_2(t)$ POTENTIOMETER

(Programmer, Two Identical Potentiometers - One In Each Wing Channel)

Function: Compensates for changes in the aerodynamic characteristics of the missile during flight.

Input: Integrating amplifier output as modified by $1/p_s$ potentiometer.

Output: Attenuated d-c signal of polarity and magnitude determined by missile position in guidance beam. Attenuation values given in discussion in Computer section.

Tests: See Computer and $f_2(t)$ discussion.

Principles:)
Location:) See Programmer Position Potentiometer.
References:)

6.4 SWITCH A (Programmer)

(NOTE: Features and references common to all programmer switches will be discussed here.)

Function: To determine the length of the complete programmer timing cycle; stops the programmer motor 40 seconds after separation.

Input: Mechanical indication of shaft position by means of cams locked to programmer shaft which is turned by an a-c motor. Power obtained from missile alternator.

Operation: The cam is cut and positioned on the shaft so as to have the switch pole connected to the alternator main at the initiation of the programmer cycle and keep it closed for 40 seconds at which time a cut-away action allows the switch to throw the pole to the second contact. The second contact is brought out to the Monitoring Panel where external power may be applied to reset the programmer. Actually each cam is composed of two sections which may be individually rotated with respect to the shaft. Thus both switch actuation time and switch dwell time may be adjusted.

Output: Power (400 cycle 115 volt) to programmer motor for 40 seconds after separation. Connection to Monitoring Panel thereafter until programmer is reset.

Principles: Microswitches and cams.

Tests: Indirect with Flight Ready Indicator and Monitoring Panel. Proper missile performance with Flight Ready Indicator test indicates each section of programmer is functioning properly. Direct test of programmer is made with Monitoring Panel. This test covers sustainer firing guidance actuation, intercept actuation and programmer speed.

Location: Programmer Chassis, Guidance Package, Forward Guidance Section, Quadrant III and IV.

References:

Operation and Description	OP 1956		p. 31
		Fig. 2-11	p. 35
		Fig. 2-13	p. 43
	Term IV Notes		
	Guidance Package		
	Special Sec. 9		
Tests	OP 1956		p. 174
	OD 8495		p. 33

6.5 SWITCH B AND B_1 (Programmer)

Function: To prevent missile launching until the programmer is in the correct starting position. Also to operate waveguide shutter (now obselete) 0.1 second after separation, protecting mixer crystal from burnout during the boost phase.

Input: Connection into firing circuitry to prevent missile firing unless switch is closed.

Output: Connection with firing circuit closed so that firing can occur when programmer is at zero time only.

Principles:
Tests:
Location:
References:

See Switch A

6.6 SWITCH C (Programmer)

Function: To fire sustainer two seconds after separation to eliminate the back blast effect that occurs when the sustainer is fired immediately at separation.

Input: Sustainer firing voltage.

Output: Sustainer firing voltage, applied to sustainer 2 seconds after missile separation from booster.

Principles:
Tests:
Location:
References:

See Switch A

6.7 SWITCH D AND F (Programmer)

Function: To short computer to ground during free flight stage to prevent wing movement due to noise generated by the receiver (thermal, shot, etc.).

Input: Output of integrating amplifier.

Output: Shorts output of integrating amplifier to ground during booster phase. Opens at 0.5 seconds after separation. Shorting to ground results in zero computer output.

Principles:)
Tests:) See switch A
Location:)
References:)

6.8 SWITCH E (Programmer)

Function: To modify gain of computer to provide necessary capture to guidance phase sensitivity ratio. Also changes receiver coding from capture to guidance beam at required time.

Input: Signals from various parts of computer gain change networks A and B and from error signal amplifier input. (See capture relay and $f_1(t)$.)

Output: Shorts or opens across proper resistors at 6 seconds after separation to provide necessary gain changes.

Principles:)
Tests:) See switch A
Location:)
References:)

6.9 SWITCH G (Programmer)

Function: To increase the gain of the roll system starting at 0.5 seconds after separation in order to compensate for the larger rolling movements produced as the result of wing movement during the beam controlled phase of flight.

Input: D-C from B- supply.

Output: Connects B- to grid of gain change amplifier through RC network at 0.5 second after separation. Gain change tube is biased off in 0.5 second after connection.

Tests: Direct test of roll gain change is made with MP.

Principles:
Location: See switch A
References:

6.10 SWITCH H AND I (Programmer)

Function: To increase wing limits and guidance system gain 18 second after separation in order to increase missile maneuverability. (See Computer.)

Input: Signals from voltage divider string of gain change network.

Output: Shorts and opens across proper resistors to provide necessary gain increase.

Principles:
Tests: See switch A
Location:
References:

6.11 SWITCH J (Programmer)

Function: Spare

PNEUMATIC-HYDRAULIC SYSTEM

7. Pneumatic-Hydraulic System
  7.1 Air Storage Bottle
  7.2 Air Shut-off Valve
  7.3 Air Filler Port and Check Valve
  7.4 Air Pressure Regulator
  7.5 Autopak
  7.6 Sump and Manifold
  7.7 Hydraulic Motor and Hydraulic Motor Flow Regulator
  7.8 Wing Hydraulic Actuators and Flow Regulators
  7.9 Rolleron Hydraulic Actuator

7. PNEUMATIC-HYDRAULIC SYSTEM

Function: (a) To provide primary source of power for missile operation during flight.
(b) To provide hydraulic (oil) pressure for actuating control surfaces during flight or tests.
(c) To provide hydraulic (oil) pressure for driving alternator during flight and during some tests.

Input: Air (dry) 400 psi to charge storage bottle. Air (dry) 750 psi for actuation during testing.

Operation: The pneumatic system converts the energy of compressed air into the energy of fluid (oil) flow. This conversion is made through an air operated hydraulic pump (autopak). The hydraulic system in turn drives a 400 cps alternator and also the wing and roll actuators. The alternator supplies electrical power for the electrical system. The wing and rolleron actuators move the wings and rolleron fins when required.

Output: Drives alternator (electrical energy); positions control surfaces in response to servo amplifiers.

Test: Flight Ready Indicator and BOFTE give indirect checks from control surface motion. Also a direct test is made on some components. (See Component discussion.)

References:

Discussion of system	OP 1955	p. 19
Pictures of components	OP 1955	pp. 20-23
Drawing of servo-valve actuator	Term III Notes Applicable Hydraulic Principles, Sec. 3	
General	Term III and IV Notes Applicable Hydraulic Principles (all sections)	
General	Term IV Notes Air and Hydraulic System (all sections)	
General	OP 1956	pp. 66-76

7.1 AIR STORAGE BOTTLE

Function: Stores air initially at 4,000 psi which provides prime energy source for actuating hydraulic system during flight.

Input: None

Output: Compressed air controlled by air shut-off valve.

Principles: Air compression.

Tests: None

Location: Forward Guidance Section, Quadrant II.

References:

Description	OP 1956	p. 66
	OP 1955	pp. 19 and 21
	Term III and IV Notes Air and Hydraulic System Sec. 1	

7.2 AIR SHUT-OFF VALVE

Function: This valve controls air flow into and out of air storage bottle. It also controls air flow to air pressure regulator during flight or testing operations.

Input: (a) Normal (flight) 4000 psi air from air storage bottle after air shut-off valve solenoid actuation. This pressure decreases as air is used from the storage bottle.
(b) Air at 750 psi during test operations.

Operation: The air shut-off valve seals the air flask until it is desired to supply air to the air-hydraulic system. The valve is of the normally closed type and is opened by means of a solenoid.

Output: See Function.

Principles: Solenoids, valves.

Test: None

Location: On air line next to air storage bottle, Forward Guidance Section, Quadrant II.

References:

Description	OP 1956		p. 66
		Fig. 3-8	p. 69
	Term III and IV Notes Air and Hydraulic System Sec. 1		

7.3 AIR FILLER PORT AND CHECK VALVE

Function: Prevents air loss through external air connection and filler port.

Input: External air supply.

Operation: One way self actuating switch permits air flow in through external air connection to air shut-off valve when external pressure exceeds internal pressure. Internal pressure will be 4000 psi when air shut-off valve is set for charging of air supply bottle. Internal air pressure will be about 600 psi during period between closure of last firing interlock switch and depletion of air supply in air storage bottle.

Output: To side port on air shut-off valve.

Principles: Check valves.

Location: Filler line runs from wing support to shut-off valve.

References:

OP 1956	p. 68
Term III and IV Notes Air and Hydraulic System Sec. 1	

7.4 AIR PRESSURE REGULATOR

Function: Regulates air pressure to autopak.

Input: High pressure air from air shut off valve.

Operation: Variable area, spring loaded orifice maintains 600 psi down stream pressure at flow rates between 35 and 80 cfm.

Output: High pressure air (600 psi) to autopak.

Principles: Pressure regulators.

Tests: Normal testing procedures do not reveal ability to handle very high pressure air. Using test air (at 750 psi) and checking hydraulic pressure when using MP checks air pressure regulator by inferences.

Location: On air storage bottle, Forward Guidance Section, Quadrant II.

References	OP 1956	p. 68
	Fig. 3-9	p. 69
	Term III and IV Notes Air and Hydraulic System Sec. 1	

NOTE: Pressure relief disk between air pressure regulator and autopak has apparently been eliminated.

7.5 AUTOPAK

Function: Converts 600 psi air flow to 1800 psi oil flow.

Input: Compressed air, low pressure oil.

Operation: Double acting differential area unit with spring loaded slide cam operated air valves. Spring loaded poppet check valves are used for oil flow.

Output: High pressure oil, air at 1 atmosphere.

Principles: Reciprocating air driven piston, hydraulic pump.

Tests: Indirect on Flight Ready Indicator, BOFTE, and MP. Direct by listening for normal sounds during operation. Proper oil pressures indicate proper operation (MP oil pressure tests), but improper oil pressures may be more probably caused by oil filter or oil line troubles.

Location: Forward Guidance Section, Quadrant I.

References:

Discussion	OP 1956	p. 70
	Fig. 3-11	p. 72
Picture	OP 1955	p. 21
Discussion	Term III and IV Notes Air and Hydraulic System Sec. 2	

7.6 SUMP AND MANIFOLD

Function: Provides elasticity in oil system which is otherwise of constant volume. Assists to establish high and low oil pressures. Smooths pressure impulses produced by normal autopak operation. Mounts oil distribution manifold and oil filter. Mounts oil system filling lines.

Input: High pressure oil from autopak. Low pressure oil from hydraulic system.

Operation: Unit is a closed cylinder divided into three compartments by two pistons, one of which is differential. The center compartment is precharged with nitrogen to 1050 psi. The total pressure is transmitted by the piston to the high pressure oil manifold compartment. The pressure ratio between the nitrogen chamber and the low pressure side is 14:1.

Output: High pressure oil to hydraulic system. Low pressure oil to autopak.

Principles: Air cushions, differential pressures.

Tests: See Con Vultee FO-R-50, 12 Feb. 53, for adjustments during charging of missile hydraulic system.

Location: Forward Guidance Section, Quadrant II.

References:

Filling	OD 8084		
Testing	Convair FO-R-50		
Description	OP 1956	Fig. 3-18	p. 71
		Fig. 3-11	p. 72
Operation	Term III and IV Notes Air and Hydraulic System Sec. 2		

7.7 HYDRAULIC MOTOR AND HYDRAULIC MOTOR FLOW REGULATOR

Function: Drives alternator at substantially constant speed.

Input: High pressure hydraulic oil.

Operation: (a) Hydraulic Motor: rotating cylinder block and tilted piston rods to transform oscillations of pistons into a rotary motion.

(b) Flow Regulator: assists in damping pressure impulses produced by autopak. Provides constant flow through motor independent of hydraulic oil supply pressure.

Output: Rotation of Alternator Shaft.

Principles: Hydraulic motors, flow regulators.

Tests: By inference (overall system performance) from Flight Ready Indicator and BOFTE tests. Monitoring Panel measures frequency of alternator voltage output.

Flow regulator valve must be closed during certain Monitoring Panel tests to prevent driving alternator for too long and thereby overheating alternator.

Location: Forward Guidance Section, Quadrant II.

References:

Description	OP 1956		p. 73
		Fig. 3-14	p. 74
Operation	Term III and IV Notes Air and Hydraulic System Sec. 4		

7.8 WING HYDRAULIC ACTUATORS AND FLOW REGULATORS

Function: Position wings in response to servo amplifier output signal.

Input: Electrical signal to servo valve solenoid from servo amplifier controls oil flow to valve actuator.

Operation: Solenoid valve is double acting for balanced loading. Flow regulator determines a maximum flow rate into actuator, hence a maximum rate of motion for wings.

Output: Piston position of valve actuator controls position of wings.

Principles: Double acting valves.

Tests: By inference from Flight Ready Indicator (wing positions) or BOFTE (wing positions and rates). By elimination on Monitoring Panel (substitution of resistive loads for solenoid valves).

References:

Description	OP 1956	p. 71
Operation	Term III and IV Notes Air and Hydraulic System Sec. 4	

7.9 ROLLERON HYDRAULIC ACTUATOR

Function: To position rollerons in response to rolleron servo amplifier output.

With the exception that no flow regulator is used in conjunction with the rolleron hydraulic regulator, the discussion under "Wing Hydraulic Actuators" applies to the rolleron hydraulic actuator (see sec. 7.8).

SUPPLEMENT TWO

A COMPARISON OF TERRIER SUBJECT MATTER WITH STANDARD CURRICULUM MATERIAL

SUPPLEMENT TWO: A COMPARISON OF TERRIER SUBJECT MATTER WITH STANDARD CURRICULUM MATERIAL

This section presents an analysis of the Terrier missile into stages and significant smaller functional units. Each stage or unit is classified as either basic or special. Since Terrier is primarily an electronic device, the classification of "basic" is used for general material similar to that covered by the Navy common core electronics curriculum up through receivers and transmitters. The classification of "special" is used for stages and units that should be emphasised, i.e., reviewed or introduced in a course designed specifically for Terrier technicians assuming a background of the "basic" subject matter. Some units are classified as basic but have unique uses in the missile system; these units are labled "basic with special uses."

A. RECEIVER SECTION

	Stage and Unit	Classification
CR 1	Hetrodyne Detector	basic
V 1	I.F. Amplifier	basic
V 2	I.F. Amplifier	basic
V 3	I.F. Amplifier	basic
V 4	I.F. Amplifier	basic
V 5	I.F. Amplifier	basic
V 6	I.F. Amplifier	basic
CR 2	Video Detector	basic
V 7	Video Amplifier (RC)	basic
CR 8	Video Pulse Shaper Crystal	special
CR 9	Video Pulse Shaper Crystal	special
V 8	Video Cathode Follower	basic
CR 3	Decoder Crystal	special
CR 4	Decoder Crystal	special
V 9	Decoder Cathode Follower	special
V 10	Pulse Stretcher	special
V 11	Pulse Amplifier	basic
V 12	Pulse Amplifier	basic
V 13	Box Car Error Detector Discharge Tube	special
CR 6	Error Detector Crystal	special
V 14	Error Detector Cathode Follower	basic
	Filter 30 cycle	special
V 15	Error Amplifier	basic
V 16	Error Output Cathode Follower	basic
V 17	A G C Amplifier	special
CR 7	A G C Clamper Crystal	special
V 19	Pulse Amplifier	basic
V 20	Blocking Oscillator	special
V 22	Reference Discriminator	special
V 23	Reference Discriminator	special
V 24	Reference Cathode Follower	basic
V 25	Flight Limiter Amplifier	special
V 26	Flight Limiter Detector (diode)	special
V 27	Flight Limiter Cathode Follower	basic
V 28	Cathode Follower	basic
V 29	Box Car (Error) Detector Diode	special
	Klystron Oscillator	special
	Phase Comparator	special
	30 cps. Filters	special
	400 cps. Filters	special

B. INTELLIGENCE CONVERTER CHASSIS

Stage and Unit	Classification
V 401 Error Amplifier	basic
V 402 Reference Phase Splitter	special
V 403 "A" Phase Comparator	special
V 404 "A" Reference Driver	basic
V 405 "B" Phase Comparator	special
V 406 "B" Reference Driver	basic
V 407 Error Signal Driver	basic

C. COMPUTER CHASSIS

Stage and Unit	Classification
"A" Rate Network	special
V 301 "A" Compensated D.C. Amplifier	special
V 302 "A" and "B" Floating Limiters	special
"A" Gain Change Network	special
V 303 "A" Integrating Amplifier and Cathode Follower	special
V 304 "A" and "B" Integral Limiters	special
V 305 "A" and "B" Fixed Limiters	special
V 306 "A" Integral and Output Cathode Follower	special
V 307 Not Used	
V 308 "B" Integral and Output Cathode Follower	special
V 309 "B" Integrating Amplifier and Cathode Follower	special
"B" Gain Change Network	special
V 310 "B" Compensated D.C. Amplifier	special
"B" Rate Network	special

D. SERVO AMPLIFIER CHASSIS

Stage and Unit	Classification
V 101 "A" Servo Power Amplifier	special
V 102 "A" Servo Driver	special

SERVO AMPLIFIER CHASSIS - (cont'd)

	Stage and Unit	Classification
V 103	"A" Servo Power Amplifier	special
V 104	"B" Servo Power Amplifier	special
V 105	"B" Servo Driver	special
V 106	"B" Servo Power Amplifier	special
T 101	Filament Transformer and Gyro Pickoff Excitation Supply	basic
	"A" Wing Feedback Potentiometer	basic with special uses
	"B" Wing Feedback Potentiometer	basic with special uses
	Roll Feedback Potentiometer	basic with special uses

E. ROLL SYSTEM UNITS

	Stage and Unit	Classification
V 107	Roll Servo Amplifier	special
V 108	Roll Servo Driver Amplifier	special
V 109	Roll Servo Amplifier	special
V 203	Compensated D.C. Amplifier	special
V 204	Roll Demodulator	special
V [illegible]	Gain change amplifier	special
	Rate Network	special
	Rolleron Feedback Potentiometer	basic with special uses
	Rolleron Position Potentiometer	basic with special uses
	1/Ps Air Pressure Potentiometer	basic with special uses
	Roll Corrector Synchro	special
	Roll Free Gyro and Pickoff Synchro	special

F. ELECTRICAL SYSTEM - POWER SUPPLY

	Stage and Unit	Classification
V 101	Double Three-Phase Rectifier	basic
V 102	Double Three-Phase Rectifier	basic
V 103	Double Three-Phase Rectifier	basic
V 104	Single Phase Full Wave Rectifier	basic
V 202	Series Regulator Positive Supply	special
V 203	Series Regulator Positive Supply	special
V 204	Series Regulator Positive Supply	special
V 205	Voltage Regulator	basic

ELECTRICAL SYSTEM - POWER SUPPLY - (Cont'd)

	Stage and Unit	Classification
V 206	Voltage Regulator	basic
V 207	Series Regulator Negative Supply	special
V 208	Series Regulator Negative Supply	special
V 209	Negative Regulator Amplifier	special
V 210	Positive Series Regulator Tube Driver	special
V 211	Positive Voltage Regulator Amplifier	special
V 401	Rectifier Voltage Regulator	basic
V 402	Rectifier Voltage Regulator	basic
V 403	Coupling Tube	special
V 404	Coupling Tube	special
	Unit 4388-483025 Klystron Voltage Reg.	special
	Alternator	special
102	Balancing Reactor	basic
	Filter - 60 Cycle Negative	basic
	Filter - 60 Cycle Positive	basic
	Output Filter Circuit	special
Sel 301	30 Volt Rectifier	basic
	Voltage Sensing Networks	special

G. ELECTRICAL SYSTEM - BOOSTER FIRING CIRCUIT

Stage and Unit	Classification
Backscratcher	basic with special uses
Backscratcher Latch and Solenoid	
Booster Latch and Latch Solenoid	
Firing Circuit Solenoids	
Contactor Release Switch	
Safety Switch	
Emergency Fire Switch	
Booster Firing Solenoid	
Booster Squib	
Flare Squib	
Control and Firing Circuit Transformers	

H. ELECTRICAL SYSTEM - POWER CHANGEOVER SYSTEM

Stage and Unit	Classification
Power Changeover Relay Missile Operate Relay Air Shutoff Valve Solenoid	basic with special uses

I. PROGRAMMER CHASSIS
(See also Roll System Units)

	Stage and Unit	Classification
V 201	"B" Computer Input Monitor (Isolating Amplifier)	basic
V 202	"A" Computer Input Monitor (Isolating Amplifier)	basic
V 206	Time to Intercept Relay Driver	special
K 201	Time to Intercept Relay	basic with special uses
K 202	Capture Relay	basic with special uses
T 201	Roll Demodulator Input Trans-	basic
	former	basic
F_1 (t)	Potentiometer - Motor Operated	basic with special uses
F_2 (t)	Potentiometer - Motor Operated	basic with special uses
	Programmer Motor	basic

J. PNEUMATIC - HYDRAULIC SYSTEM

	Stage and Unit	Classification
A	Air Storage Bottle	Basic, for air and hydraulic subject matter, with special uses
B	Air Shutoff Valve	
C	Air Check Valve	
D	Air Pressure Regulator	
E	Autopak	
F	Sump and Manifold	
G	Hydraulic Motor and Flow Regulator	
H	Wing Hydraulic Actuators and Flow Regulators	
I	Rolleron Hydraulic Actuators	